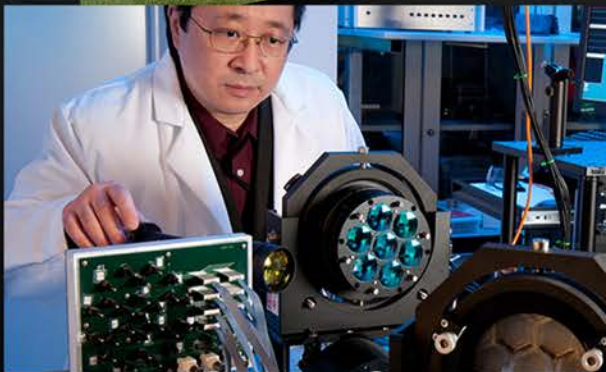


# *Open Campus Opportunities*



U.S. ARMY  
**RDECOM**  
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

**ARL**

U.S. Army Research Laboratory

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July 2014

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## INTRODUCTION

The mission of the U.S. Army Research Laboratory (ARL) is to provide innovative science, technology, and analyses to enable full spectrum Army operations, now and into the future. To execute this mission, ARL leverages the substantial intellectual resource represented by the global academic scientific research community. Formation of a collaborative and transparent relationship with this community, with industry, and with small business through the Open Campus initiative offers the prospect for enhanced discovery and innovation, and effective execution of basic and applied research programs in a variety of technical focus areas of high Army interest.

ARL's Open Campus initiative is a collaborative endeavor, with the goal of building a science and technology ecosystem that will encourage groundbreaking advances in basic and applied research areas of relevance to the Army. Through the Open Campus framework, ARL scientists and engineers (S&Es) will work collaboratively and side-by-side with visiting scientists in ARL's facilities, and as visiting researchers at collaborators' institutions. The global academic community, industry, small businesses, and other government laboratories benefit from this engagement through collaboration with ARL's specialized research staff and unique technical facilities. These collaborations will build research networks, explore complex and singular problems, enable self-forming expertise-driven team building that will be well-positioned for competitive research opportunities, and expose scientists, engineers, including professors and students to realistic research applications and perspectives, helping to ensure our nation's future strength and competitiveness in these critical fields.

ARL's technical portfolio encompasses a broad array of technical areas as well as technology maturity levels, from discovery of first-recognized phenomena to innovative systems. ARL's research in focused topic areas such as Energy & Energetics, Network Sciences, Autonomous Systems, and Imaging & Image Processing is highlighted in the Research@ARL collection, which may be found at [www.arl.army.mil/ResearchARL](http://www.arl.army.mil/ResearchARL). The Open Campus initiative opened select segments of our extended campus network in the summer of 2014. The Open Campus will accommodate both U.S. citizens and foreign national researchers who come to ARL to collaborate in research areas of mutual interest. Additional Open Campus laboratories and office spaces, as well as a virtual collaboration infrastructure, will be added in the future.

This document describes ARL's strategic research interests, facilities, and collaborative research opportunities within the Open Campus framework. Research opportunities include visiting scientist and researcher exchanges between ARL and academic, government, industrial, and small business collaborators internationally, as well as postdoctoral fellowships and internships. Additional opportunities may be identified within the research areas even if a specific opportunity is not listed. The final section includes Frequently Asked Questions (FAQs).

For additional information, please contact ARL Open Campus Program Manager Ms. Wendy Leonard at [wendy.a.leonard.civ@mail.mil](mailto:wendy.a.leonard.civ@mail.mil).

## THE OPEN CAMPUS CONCEPT

The concept of a defense laboratory was inspired by Thomas Edison's vision of "a great research laboratory" maintained by the Government. This vision led to the creation of the Naval Research Laboratory in 1923.<sup>1</sup> In 1945, Vannevar Bush's concepts documented in *Science: The Endless Frontier* became a model for how the United States would pursue its scientific endeavors.<sup>2</sup> Bush stressed the necessity of establishing a robust and synergistic university, industry, and government laboratory research system.<sup>3</sup> Over the past 60 years, organizational changes and consolidations have created the National Laboratories structure and a DoD research laboratory structure now known as the Defense Laboratory Enterprise (DLE).<sup>4</sup> However, the DoD research laboratory internal structure and operation have not changed since their establishment, while the global university and industry research capabilities have evolved with the changing research and economic environments. This shift and the rigid and insular nature of the DLE have caused an erosion of the university/industry/government laboratory synergy that is vital to the discovery, innovation, and transition of science and technology critical to national security. In addition, the pace of technological change from 1990 to the present far exceeds the technology pace observed from 1950 to 1990 and will more than likely continue to increase in the future. The globalization of technology requires novel and new collaboration mechanisms that will reenergize the university/industry/government laboratory synergy.

ARL is adaptive and responsive to the challenges of 21st century national security. While the nature of our mission requires that segments of our research be restricted, it is widely acknowledged that innovation depends on bringing multiple disciplines together to engage in collaborative projects that often yield unpredictable, but highly productive, results. Formal and informal interactions among scientists lead to knowledge-building and research breakthroughs. By bringing together academia, industry, small business, and government to address fundamental research problems, the Army can enhance its performance through on-site R&D collaboration, at both ARL and collaborator locations. ARL will implement an Open Campus initiative as part of our business model to foster better collaboration across industry, academia, and government, attracting and leveraging the best and brightest across the collective research community to more effectively produce transformative science and technology. Participation in ARL's Open Campus will provide ready access to unique facilities, specialized researchers, and collaborative resources for all partners, including foreign nationals.

This represents a transition within our current business model, so during the early phases of the Open Campus initiative, escorting of foreign national collaborators may be required. Restricted unescorted access of foreign national collaborators in designated Open Campus areas will be introduced in a phased approach starting in the fall of 2014, and expanded as the initiative grows. In addition to collaborative engagement in existing ARL facilities, future phases of ARL's Open Campus will include opportunities for partners to establish new on-site facilities on our campuses.

Currently, ARL seeks to attract academic, government, small business, and industry partners for collaborative engagement. This document outlines research areas of interest to ARL and provides descriptions of collaboration

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<sup>1</sup> History of the Naval Research Laboratory. <http://www.nrl.navy.mil/about-nrl/history/>. 2013.

<sup>2</sup> Unlocking Our Future: Toward a New National Science Policy. U.S. House of Representative Committee on Science. 1998.

<sup>3</sup> Bush, Vannevar. *Science: The Endless Frontier, A Report to the President*. July 1945.

<sup>4</sup> Defense Laboratory Enterprise. <http://www.acq.osd.mil/rd/laboratories/>. 2013.



opportunities and the name, telephone number, and e-mail address for the ARL Principal Investigator. These research areas are represented in ARL's Technical Strategy and include Computational Sciences, Materials Sciences, Sciences for Maneuver, Information Sciences, Sciences for Lethality and Protection, Human Sciences, and Assessment and Analysis. Each of these research areas focus on critical challenges that arise in the extreme operational and threat environment in which the Army operates.

## ARL LOCATIONS

ARL has five primary sites across the United States, as shown below, with collaborative opportunities at each. ARL's Open Campus pilot program will be centered in the Adelphi Laboratory Center (ALC) in 2014, and include ARL's Specialty Electronic Materials and Sensors Cleanroom (SEMASC), a 15,000 square foot Class 10/100 cleanroom equipped to process novel materials and device structures down to nanoscale dimensions, and ARL's Microsystem Indoor Testing Ground, an enclosed cityscape enabling experiments with unattended ground and air intelligent systems. Other collaborative opportunities will be coordinated on a case-by-case basis during the Open Campus pilot.

ADELPHI LABORATORY CENTER (ALC), MD



Microsystem Indoor Testing Ground



Specialty Electronic Materials and Sensors Cleanroom (SEMASC)



ABERDEEN PROVING GROUND, MD



ORLANDO, FL



WHITE SANDS MISSILE RANGE (WSMR), NM



RALEIGH-DURHAM, NC

## RESEARCH AREAS

### Computational Sciences

ARL's basic and applied research in Computational Sciences is focused on advancing the fundamentals of predictive simulation sciences, data intensive sciences, computing sciences, and emerging computing architectures to transform the future of complex Army applications. Gains made through these underpinning multidisciplinary research efforts and exploiting emerging advanced computing systems will lead to scientific breakthroughs that are expected to have significant impact on Army materiel systems. Technologies resulting from this multidisciplinary research, collaboratively with other ARL S&T campaign innovations, will have a significant impact on Power Projection Superiority, Information Supremacy, Lethality & Protection Superiority, and Soldier Performance Augmentation for the Army of 2030.

Computational Sciences uses advanced computing to understand and overcome complex fundamental challenges simultaneous to improving approaches of importance to the Army, including weapon systems design; materials-by-design; information dominated and networked battle command applications; system-of-systems analyses; human performance modeling; platform maneuverability; and tactical supercomputers. There are natural synergies among the challenges facing Computational Sciences and ARL's other S&T campaigns. Synergistic advances across all campaigns are expected to enable next-generation scientific breakthroughs. The Computational Sciences area heavily relies on ARL's research expertise and facilities devoted to emerging advanced computing architectures, mobile High Performance Computing (HPC), multiscale and interdisciplinary predictive simulation sciences, multidimensional distributed data analytics, and computing sciences. Discoveries and innovations made in this area will exert a significant impact on the Army of the future. Computational Sciences technical emphasis areas include Predictive Simulation Sciences, Data Intensive Sciences, Computing Architectures, and Computing Sciences.

**Predictive Simulation Sciences** concentrates on understanding and exploiting the fundamental aspects of verified and validated computational simulations that predict the response of complex Army systems and guide Army materiel design, particularly in cases where routine experimental tests are not feasible.

**Data Intensive Sciences** focuses on understanding and exploiting the fundamental aspects of large-scale multidimensional data analytics. Experiments, observations, and numerical simulations are on the verge of generating petabyte quantities of data. These massive amounts of data are distributed across disparate locations and pose a challenge in providing real-time analytics that support U.S. military operations.

**Computing Architectures** concentrates on understanding and exploiting the fundamental aspects of hardware and associated system software for emergent and future computing architectures for mobile, scientific, and data intensive applications. Computing systems include both mobile and fixed/virtual architectures optimized for faster communications, lower power consumption, larger hierarchical memory, novel and robust algorithms, resilience, and HPC networking.

**Computing Sciences** concentrates on understanding and exploiting the fundamental aspects of computer science research related to ease of programming, computing environments, languages, and reusable programming models for Army-specific applications.

Active research areas and specific projects seeking Open Campus collaborative engagement include:

### Computational Fluid Dynamics (CFD)

Research in computational fluid dynamics, turbulence modeling, and grid generation is performed with emphasis on nonlinear and unsteady aerodynamics.

Principal Investigator:      Jubaraj Sahu      [jubaraj.sahu.civ@mail.mil](mailto:jubaraj.sahu.civ@mail.mil)      (410) 306-0798

### Computational Fluid Dynamics of Reacting Flows for Propulsion

CFD is used in detailed numerical models of high-pressure reacting flows, including interior ballistics of guns, gun muzzle flow for blast/flash mitigation, and for rocket motor research. For success of the numerical models run on high-performance computers (HPCs), necessary inputs include detailed chemical kinetics and physical simulators for validation.

Principal Investigators:      Richard Beyer      [richard.a.beyer10.civ@mail.mil](mailto:richard.a.beyer10.civ@mail.mil)      (410) 278-6184  
                                 Michael Nusca      [michael.j.nusca.civ@mail.mil](mailto:michael.j.nusca.civ@mail.mil)      (410) 278-6108  
                                 Michael McQuaid      [michael.j.mcquaid.civ@mail.mil](mailto:michael.j.mcquaid.civ@mail.mil)      (410) 278-6185

### Supporting Facility: Propulsion Science Branch Experimental Facilities (APG)

The Propulsion Science Branch has developed the capability to obtain data to validate our reacting CFD codes related to gun propulsion. High-pressure environments, including research gun firings, are safely accommodated. Novel experimental designs are developed as required.

**Equipment Available:** Ballistic simulators for acquisition of validation data for IB models. Optical diagnostics of chemistry, temperature, and pressure in muzzle flow field.

### Heterogeneous Computing

This effort is focused on achieving high performance while using disparate processing core technologies. Algorithm design and software engineering approaches will be investigated to effectively partition and use binary processing cores to reduce time to solution for Army-relevant problems. Factors such as performance, portability, and power will be considered in conjunction with developing new models to quantify computing capabilities in hybrid systems to facilitate algorithm signature mapping to available resources.

Principal Investigator:      Song Park      [song.j.park.civ@mail.mil](mailto:song.j.park.civ@mail.mil)      (410) 278-5444



**Benchmark Suite Development (APG)**

ARL is developing a suite of parallel number-crunching benchmarks to evaluate and analyze the performance of heterogeneous computing systems. This includes software from the SHOC (Scalable Heterogeneous Computing) benchmark suite as well as home-developed codes and approaches using languages such as OpenCL. This project will involve developing several optimization strategies for benchmark kernels and developing canonical tests for performance.

**Principal Investigator:** Jamie Infantolino      [jamie.k.infantolino.ctr@us.army.mil](mailto:jamie.k.infantolino.ctr@us.army.mil)      (410) 278-7121

**Autotuning for Enhanced Software Performance (APG)**

This effort is devoted to developing technologies to allow HPC software to optimize within a runtime environment. Kernels will be automatically generated to test parameter spaces within complex hybrid core technologies where instruction scheduling and other compiler phase ordering passes lead to intractability for efficiency assessment a priori. This effort is focused on combining algorithmic development and software engineering to maximize efficiency of software across a myriad of cores with limited developer effort.

**Principal Investigator:** Dale Shires      [dale.r.shires.civ@mail.mil](mailto:dale.r.shires.civ@mail.mil)      (410) 278-5006

**Energy Efficient Software Improvements for Constrained Devices (APG)**

This effort is focused on investigating and developing more efficient approaches to software design and implementation on disparate core technologies to reduce energy consumption. Areas of interest include code refactoring, variations in low-level instruction scheduling, and dynamic gating utility, as well as developing parameterized models for software execution using various binary processing configurations to discover relationships between power utilization and software efficiency.

**Principal Investigator:** Song Park      [song.j.park.civ@mail.mil](mailto:song.j.park.civ@mail.mil)      (410) 278-5444

**Meso- and Microscale Forecast Model Validation**

Data from the Meteorological Sensor Array (MSA) and other sources are being used to validate meso- and microscale numerical weather prediction (NWP) models at sub-kilometer grid resolutions. Model assessment tools developed by other organizations are being adapted, and various statistical analysis methodologies and Geographic Information Systems techniques are being employed to conduct the validations. Data collected from the MSA is statistically analyzed against results from numerical weather prediction models to assess their accuracy.

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David Knapp      [david.i.knapp.civ@mail.mil](mailto:david.i.knapp.civ@mail.mil)      575-678-4574

**Supporting Facility: Meteorological Sensor Array (MSA) (WSMR)**

The MSA is a first-of-its-kind array of meteorological (Met) sensors designed to be emplaced to exactly overlay meso- and microscale forecast model grid points, enabling in-situ and remotely sensed Met observations that will more precisely assess and validate the accuracy of the models.

**Equipment Available:** Ten-meter Met towers with standard thermodynamic instrumentation; three-axis sonic anemometers; scintillometers; SODAR; triple LIDAR configuration.

## Neurosynaptic Computing

Investigate the emerging topic of neurosynaptic computing that roughly mimics natural processing phenomena in the brain. Elaborate on and develop additional biologically based computing models and determine how binary processors based on this design could be used for neurocognitive applications within the Army sphere of interest.

**Principal Investigator:** Manny Vindiola      [manuel.m.vindiola.civ@mail.mil](mailto:manuel.m.vindiola.civ@mail.mil)      (410) 278-9151

### Algorithm Development and Assessment for Neurosynaptic Architectures (APG)

Develop computational science algorithms using neurosynaptic computing models for Army-relevant problem spaces such as reasoning and cognition. Investigate alternative and/or additional biologically based models for binary execution in order to more accurately mimic human brain processing and provide accurate and efficient processing solutions.

**Principal Investigator:** Manuel Vindiola      [manuel.m.vindiola.civ@mail.mil](mailto:manuel.m.vindiola.civ@mail.mil)      (410) 278-9151

## Novel Applications for Advanced and Tactical High-Performance Computing

Research and develop new capabilities for Soldiers based on mobile and tactical High-Performance Computing (HPC). Focus on novel real-time processing capabilities to reduce network load and increase Soldier effectiveness. Areas of interest include line-of-sight-related processing, electronics warfare, vehicle navigation, etc.

**Principal Investigator:** Song Park      [song.j.park.civ@mail.mil](mailto:song.j.park.civ@mail.mil)      (410) 278-5444

### Real-Time Operating Systems for GPU-Based Tactical HPC (APG)

Graphics Processing Units (GPUs) are accelerator technologies that can allow for large-scale number crunching in deployed footprints. While these processors have a large capacity, they were not engineered with general-purpose inclusion into deployed systems with real-time processing restrictions. This project will investigate the state-of-the-art in incorporating this technology into deployed systems and suggest improvements in an Army-centric application.

**Principal Investigator:** Song Park      [song.j.park.civ@mail.mil](mailto:song.j.park.civ@mail.mil)      (410) 278-5444

## Quantum Monte Carlo Studies

Quantum Monte Carlo studies and their use in and connections to quantum algorithms, quantum simulations (e.g., in optical lattices), and quantum walks. Related studies include approaches to overcoming the Fermion sign problem, particularly through an understanding of wave function nodal structure.

**Principal Investigator:** Peter J. Reynolds      [peter.j.reynolds16.civ@mail.mil](mailto:peter.j.reynolds16.civ@mail.mil)      (919) 549-4345

#### **Quantum Monte Carlo Studies (*North Carolina State University*)**

Conduct Quantum Monte Carlo studies primarily in diffusion and their use in and connections to quantum algorithms, quantum simulations (e.g., in optical lattices), and quantum walks. Related studies include approaches to overcoming the Fermion sign problem, particularly through an understanding of wave function nodal structure.

**Principal Investigator:** Peter J. Reynolds      [peter.j.reynolds16.civ@mail.mil](mailto:peter.j.reynolds16.civ@mail.mil)      (919) 549-4345

#### **Software Defined Networking (SDN)**

Investigate the use of the new paradigm of SDN in network architecture and protocols for heterogeneous (optical, wireless, etc.) networks. Develop new approaches using SDN for packet forwarding and policy enforcement. Embed cognitive learning capabilities in SDN controllers.

**Principal Investigator:** Vinod Mishra      [Vinod.k.mishra.civ@mail.mil](mailto:Vinod.k.mishra.civ@mail.mil)      (410) 278-0114

#### **Dynamic Optical Networking (DON)**

Investigate the use of new CORONET protocols like 3-Way Handshake (3WHS) and others to develop dynamic optical networking architectures. Extend software defined networking ideas to the optical layer.

**Principal Investigator:** Vinod Mishra      [Vinod.k.mishra.civ@mail.mil](mailto:Vinod.k.mishra.civ@mail.mil)      (410) 278-0114

#### **Quantum Communications**

Investigate the modeling, simulation, and implementation of multi-node Quantum Communication Networks (QCN) in free-space and wired environments. Develop more efficient quantum communication algorithms and protocols. Develop Quantum Metadata communication interfaces between quantum and classical channels.

**Principal Investigator:** Vinod Mishra      [Vinod.k.mishra.civ@mail.mil](mailto:Vinod.k.mishra.civ@mail.mil)      (410) 278-0114

#### **Quantum Computing**

Investigate the use of adiabatic quantum computing and annealing for NP-Hard MAXSAT reducible problems. Investigate the use of both adiabatic algorithms and algorithms adhering to the quantum circuit model for classes of problems spanning optimization algorithms to quantum networking and quantum routers.

**Principal Investigator:** Dale Shires      [dale.r.shires.civ@mail.mil](mailto:dale.r.shires.civ@mail.mil)      (410) 278-5006

**Investigation of the Dwave Adiabatic Quantum Computer (APG)**

Investigate the use of adiabatic quantum computing for optimization problems found in scheduling in cloudlet-based networks of computers.

**Principal Investigator:** Radhakrishnan Balu [radhakrishnan.balu.ctr@mail.mil](mailto:radhakrishnan.balu.ctr@mail.mil) (410) 278-6174

**Quantum Circuit Algorithms for Quantum Routers (APG)**

Investigate the algorithmic design and constraints when dealing with quantum entanglement and networking over long distances, hence the need for quantum routers.

**Principal Investigator:** Radhakrishnan Balu [radhakrishnan.balu.ctr@mail.mil](mailto:radhakrishnan.balu.ctr@mail.mil) (410) 278-6174



## Materials Research

Materials Research is basic and applied research focused on gaining a fundamental understanding of structural, electronic, photonic, and energy materials & devices. Exemplary of Army and DoD-relevant high-interest research areas supported through these efforts include multifunctional materials; high field responsive materials; hierarchically designed & fabricated materials; semiconductor materials & devices; generation-after-next electronics; and synthetic biology. ARL's basic and applied research in materials focuses on scientific discovery and innovative problem-solving to provide superior materials and devices needed to achieve lasting strategic land power dominance. Materials research cross-cuts ARL's four focused S&T campaigns in Human Sciences, Information Sciences, Sciences for Lethality and Protection, and Sciences for Maneuver by providing materials with superior properties to address emerging requirements and capabilities for all Army platforms.

The Army of 2030 will require materials with unprecedented capabilities that can be rapidly grown or synthesized, and processed cost-effectively to enable Army platforms that are highly mobile, information reliant, lethal, and protected. ARL's Materials Research Campaign addresses the future Army's need to rapidly respond to emerging threats and to eliminate tactical surprise by creating a materials-by-design and on-demand enterprise, and a manufacturing science engine to ensure rapid progression from materials discovery to delivery, with the goal of producing materials in greatly reduced time frames and at a fraction of the cost compared to today.

ARL's Materials Research Campaign builds on fundamental pillars of materials science, physics, mathematics, computational chemistry, synthetic chemistry, biology, and engineering to conduct research in areas including Advanced Experimental Techniques; Modeling and Simulation; Bridging the Scales—a materials-by-design paradigm; Material Property Characterization to measure materials properties and performance to inform the research community across the scales; and Growth or Synthesis and Processing—a materials-on-demand paradigm.

Key enablers, which are expected to lead to disruptive discoveries yielding new Army capabilities, are emphasized. Discovery enablers include biological and bio-inspired materials, metamaterials, two-dimensional and nanoscale materials, and multifunctional and hierarchical materials. Recent scientific emphasis areas that promise disruptive capabilities include quantum science to alter time, space, and information processing; the coupling of energy fields to matter to create new materials and selectable system responses with vast performance improvements; and interfacial science research from which many key Army capabilities are enabled. Recent discoveries in these scientific areas are setting the course of future ARL research.

Materials research areas of specific emphasis include Structural Materials; Electronics; Photonics; Energy & Power; Biotechnology & Bio-Inspired; Lethality & Protection; and Manufacturing Science, Processing, & Sustainment.

**Structural Materials** is focused on novel and specialized materials to enhance the structural efficiency and systems performance of advanced platform structures while maintaining the same or greater levels of protection compared to today's platforms.

**Electronics** is focused on specialized electronic materials and devices and circuits to achieve Army dominance over the entire electromagnetic spectrum, particularly in contested environments. The two primary thrusts of this area are Energy-Efficient Electronics and Hybrid Electronics. Energy-Efficient Electronics is focused on low-power-demand

electronic components having increased performance capabilities, and Hybrid Electronics focuses on high-performance semiconductor-based conformable, flexible electronics for advanced sensors and processors.

**Photonics** is focused on materials and devices for photonic sensors and sources, scalable high energy lasers, secure communications via quantum networking, and protection of sensors and human eyes against high power and short pulse laser threats.

**Energy & Power** is focused on materials and devices for more efficient power generation, energy storage, energy harvesting, fuel processing, micropower, and novel alternative energy solutions at lower cost.

**Biotechnology & Bio-Inspired** is focused on new biological materials derived through synthetic biology as well as classical approaches. Novel biological materials are combined with inorganic devices to sense chemical and biological agents, generate power from organic sources, and produce materials to create new protection designs inspired by nature.

**High Strain Rate & Ballistic Materials** is focused on novel and specialized materials to enhance the performance and efficiency of Army weapons and protection systems, including lightweight extreme performance materials, novel energetic materials, and energy absorbing materials.

**Manufacturing Science, Processing, & Sustainment** is focused on discovery, innovation, and maturation of manufacturing innovations to facilitate agile, adaptive, mobile processing & manufacturing capabilities to enable superior performance and implementation of cost reduction methodologies. Sustainability is focused on understanding material properties and degradation mechanisms to improve durability of Army systems in extreme environments.

Active research areas and specific projects seeking Open Campus collaborative engagement include:

#### Piezoelectric MicroElectroMechanical Systems (PiezoMEMS) Technology

Research based on improving the current state of the art in piezoelectric thin film materials and fabrication processing, device modeling and simulation, and material and prototype testing and evaluation used as sensors, actuators, and microelectromechanical structures for RF communication and radar systems (e.g. switches, phase shifters, resonator and filters, transformers, tunable microwave components), mm-scale robotics (e.g. mobility actuators and proprioceptive sensors), position, navigation, and timing, or PNT (e.g. gyroscopes, accelerometers, and integrated package and assembly strategies).

**Principal Investigator:** Ronald Polcawich      [ronald.g.polcawich.civ@mail.mil](mailto:ronald.g.polcawich.civ@mail.mil) (301) 394-1275

#### Supporting Facilities: Specialty Electronic Materials and Sensors Cleanroom (SEMASC) (ALC)

This 15,000 gross square feet Class 10 and 100 cleanroom facility houses a comprehensive set of semiconductor fabrication tools—including specialty material deposition, etch, lithography, and thermal—and research characterization systems for the next generation of sensors and electronic devices for the Soldier. These systems enable the fabrication of advanced micro and nanoscale devices using an extremely broad set

of device materials including silicon; III-V and II-VI semiconductors; silicon carbide; quartz; lead zirconate titanate (PZT) and aluminum nitride piezoelectrics; many metals and oxides; and graphene and carbon nanotubes. Support applications fabricated with these devices range from bio- and trace gas detection; secure communication (radiofrequency [RF] switches, filters, varactors, and tunable inductors); improvised explosive device (IED) detection (RF switches and filters); mobile sensor platforms for Soldier Intelligence, Surveillance, and Reconnaissance (bio-inspired microflight and terrestrial actuation, ultrasonic motors, bio-inspired sensors); traumatic brain injury (shock sensor, G-switch); RF (resonators, switches); power generation (microturbine, energy harvesting); infrared, ultraviolet, and optical detectors and emitters (imagers, lasers, LEDs); on-chip energetic devices (microthrusters, fusing); and next-generation flexible, transparent, and high performance electronics and devices based on graphene and other 1D and 2D materials.

### Aperiodic to Nanostructured Materials

Research based on experimental, computational, and analytic solutions relates to the design and thermal stabilization of metastable materials; specific focus is on the effective utilization and exploitation of nanostructured materials via the discovery of new compositions and/or defect and interface engineering, such as novel multiphasic solvent-solute combinations, augmented with grain size reduction and grain boundary modification techniques. Approaches entail the use of thermodynamic and kinetic principles to develop materials with unprecedented or greatly improved mechanical, thermal, or chemical properties.

**Principal Investigator:** Kristopher Darling      [kristopher.darling.civ@mail.mil](mailto:kristopher.darling.civ@mail.mil) (410) 306-0862

**Supporting Facility:** Atmospheric Plasma Modification Laboratory (APG) Laboratories to perform atmospheric and low vacuum plasma modification of materials. Laboratories to characterize the modification of such materials.

**Equipment Available:** Plasma Jet, plasma roll to roll, Kratos XPS, Nicolet FTIR, contact angle goniometer, Hitachi SEMs, planar atmospheric plasma system, plasma-enhanced chemical vapor deposition.

### Atmospheric Plasma Modification of Materials

Research and development of novel, scalable methods to modify the surface of materials using plasma to improve adhesion, reduce defects, kill microorganisms, etc., without affecting bulk properties. Surface modification of and deposition of thin coatings on materials surfaces using plasma-assisted wet chemistry and spray deposition techniques. Material analysis techniques including SEM, XPS, contact angle goniometry, FTIR, XRD, and tensile strength testing will be employed. Development and characterization of novel polymers/fibers, polymer blends/hybrids, nanomaterials, new process methods for applying or modifying polymers to increase service life, environmental durability, and providing chemical-biological protection/detection and/or ballistic protection. Development of experimental and theoretical methods to explore the potential of applying plasma technology to the growth of thin conformal multifunctional coatings for specific Army applications.

**Principal Investigator:** Andres Bujanda      [andres.a.bujanda.civ@mail.mil](mailto:andres.a.bujanda.civ@mail.mil) (410) 306-0680

**Supporting Facility:** Atmospheric Plasma Modification Laboratory (APG) Laboratories to perform atmospheric and low vacuum plasma modification of materials. Laboratories to characterize the modification of such materials.

**Equipment Available:** Plasma Jet, plasma roll to roll, Kratos XPS, Nicolet FTIR, contact angle goniometer, Hitachi SEMs, planar atmospheric plasma system, plasma enhanced chemical vapor deposition.

### Advanced Concepts for RF Antennas

Develop specialized and low-profile, high performance antennas and phased arrays for Army sensor, communications and electronic warfare systems using novel design techniques and specialized materials. Research includes investigation of metamaterial and metaferri design techniques for extremely low-profile, broadband antennas and the application of emerging nanomaterials (e.g. carbon nanotubes, graphene) for durable, textile integrated and flexible antennas.

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### Electrically Small Antennas (ALC)

Develop small antennas to replace conventional dipole antennas with additional operational features and shapes. This includes structures that are produced using 3-D printers and make use of surface-filling curve concepts and metamaterial-enhanced designs. Optimizing the designs for broadband matching and simple feeding mechanisms are goals.

**Principal Investigator:** Amir Zaghloul [amir.i.zaghloul.civ@mail.mil](mailto:amir.i.zaghloul.civ@mail.mil) 301-394-0886

### Metasurfaces and/or Periodic and Random Metamaterials for Broadband, Low-profile Antennas (ALC)

Develop supporting surfaces for antennas to produce desired reflection phase properties that result in low profiles for the antenna/surface combination. The metasurfaces may fall under light-weight metaferri surfaces for high permeability, electromagnetic band-gap structures for high-impedance surfaces, and tunable surfaces for adaptive reflection properties of surfaces, all operating over a broadband. Additionally, investigate the theoretical underpinnings and design of periodic and randomly oriented metamaterials for broadband low-profile antenna design through analysis, electromagnetic simulation and prototype measurement.

**Principal Investigator:** Amir Zaghloul [amir.i.zaghloul.civ@mail.mil](mailto:amir.i.zaghloul.civ@mail.mil) 301-394-0886

### Magnetic Metamaterials for Broadband, Low-profile Antennas (ALC)

Design of low-profile magnetic metamaterials for broadband antenna design through analysis, electromagnetic simulation and prototype measurement.

**Principal Investigator:** Steven Weiss [steven.j.weiss14.civ@mail.mil](mailto:steven.j.weiss14.civ@mail.mil) 301-394-1987

### Supporting Facility: Antennas Laboratory (ALC)

**Equipment Available:** Multi-room laboratory that enables antenna design/simulation, fabrication, and measurement. Equipment includes: Computer with Ansoft HFSS, EMSS FEKO, Agilent ADS/Momentum, REMCOM XFtd, network analyzers, spectrum analyzers, oscilloscopes, miscellaneous electronics, circuit board router, 3-D printer.



**Supporting Facility:** Far-field Anechoic Chamber (ALC)

**Equipment Available:** Indoor facility that enables accurate antenna radiation pattern and gain measurements (lower frequency limit of ~200 MHz). Equipment includes: Anechoic chamber, standard gain horn antennas, signal generator, RF receivers, network analyzer, and power meter.

**Supporting Facility:** Near-field Anechoic Chamber (ALC)

**Equipment Available:** Indoor facility that enables accurate antenna radiation pattern and gain measurements in a compact, convenient chamber (lower frequency limit of ~1 GHz). Equipment includes: Anechoic chamber, standard gain horn antennas, signal generator, RF receivers, network analyzer, and power meter.

**Supporting Facility:** Electromagnetic Simulation Tools (ALC)

**Software Available:** Simulation tools support the analysis and design of developed antennas and concepts. This includes full-wave simulation tools such as FEKO, HFSS, and CST, in addition to special purpose software such as Rotman Lens Analysis and other in-house developed tools.

## Microscale Heat Transport

Research into heat propagation in electronic devices, and coupled electronic-thermal-material interactions; non-standard measurement techniques for characterizing solid properties in semiconductor devices, and interfacial heat transfer across dissimilar solid, liquid, and gaseous material boundaries; electronics packaging thermal improvement techniques including low impact microchannel cooling, heat spreading, interface materials, and air-side convection enhancement.

**Principal Investigator:** Nicholas Jankowski    [nicholas.r.jankowski.civ@mail.mil](mailto:nicholas.r.jankowski.civ@mail.mil)    (301) 394-2337

## Phase Change Thermal Sciences

Research on enhanced steady and transient thermal transport using material phase change; enhancing and improving prediction of boiling mode heat transfer under steady and transient conditions; improving dropwise condensation heat transfer and enhancing condensate removal. Additional focus on using solid-liquid phase change to bridge source-to-sink time constant mismatches for thermal protection of high-rate electronics, and thermal buffering of vehicle, climate control, and power systems; includes investigations into high latent heat, high conductivity materials and supercooling reduction.

**Principal Investigator:** Nicholas Jankowski    [nicholas.r.jankowski.civ@mail.mil](mailto:nicholas.r.jankowski.civ@mail.mil)    (301) 394-2337

**Supporting Facility:** Thermal Sciences Laboratory (ALC)

Laboratory to perform tests on high power electronics cooling, single and two-phase flow loops, and packaging materials.

**Equipment Available:** Water and dielectric liquid flow loop test stand (>5kW), humidity controlled condensation test stand, FLIR LWIR, custom 1DSS interface conductance tester, 20g rotary acceleration thermo-fluid test stand.

## Chemical Agent Resistant Coatings (CARC) Development

New agents and new analysis of CARC show that CARC has more vulnerabilities than previously known. As a result, work is needed to be able to understand why some coatings formulations are resistant to some chemical agents and why some fail vs. the same or other agents.

**Principal Investigators:** John Escarsega [john.a.escarsega.civ@mail.mil](mailto:john.a.escarsega.civ@mail.mil) (410) 306-0693  
John La Scala [john.j.lascala.civ@mail.mil](mailto:john.j.lascala.civ@mail.mil) (410) 306-0687

### Supporting Facility: Coatings Suite and Materials and Manufacturing Sciences Division (MMSD) Laboratories (APG)

Laboratories to formulate and characterize coatings components and the properties and performance of coatings.

**Equipment Available:** spray hoods, elcometer, profilometer, contact angle goniometer, high-speed mixers, Varian FTIR, Atlas weatherometers, QUVs, Bruker AFMs, Hitachi SEMs, NEC 1.7 Megavolt Ion Accelerator.

### Coatings Fundamental Research (APG)

Fundamental research and analysis to support the development of coatings, understanding of the chemical resistance of coatings, reducing the environmental footprint, and reducing materials degradation/corrosion. Formulate epoxy, polyurethane, and other thermosetting materials for use as coatings. Characterize thermosetting resins for chemical resistance via positron annihilation spectroscopy (PALS), solvent absorption, and other studies. Characterize thermal and mechanical analysis of organic-based films and coatings. Formulate and prepare model coatings and coatings for Army applications using thermosetting resin binders. Provide expert analysis of product performance and characteristics through various instrumental methods. Develop structure/property relationships for coatings materials via measurement of material properties and analysis of chemical, nano, and micro-structure using tools such as dynamic mechanical analysis (DMA/DMTA), differential scanning calorimetry (DSC), PALS, infrared spectroscopy (IR), microscopy, and scanning electron microscopy (SEM). Conduct performance testing of coatings according to military specifications and related ASTM protocols. Develop improvements for quality of applications, products, and/or procedures. Formulate and evaluate camouflage coatings and related epoxy coatings used to extend life cycles of coating performance. Formulate improved coatings for resistance to chemical infiltration/absorption, resistance to degradation, mitigation of corrosion, and reduction in environmental footprint. Evaluate materials for corrosion resistance using accelerated weathering techniques and coatings evaluation techniques, including electrical impedance spectroscopy (EIS).

**Principal Investigators:** John Escarsega [john.a.escarsega.civ@mail.mil](mailto:john.a.escarsega.civ@mail.mil) (410) 306-0690  
John La Scala [john.j.lascala.civ@mail.mil](mailto:john.j.lascala.civ@mail.mil) (410) 306-0687

## Corrosion at the Nano/Micro Scale

Perform fundamental corrosion research at the micro/nano scale. Use and develop new techniques to analyze and understand corrosion at micro/nano scale that could be used to potentially mitigate corrosion.

**Principal Investigator:** Joseph Labukas [joseph.p.labukas.civ@mail.mil](mailto:joseph.p.labukas.civ@mail.mil) (410) 306-4939

**Supporting Facility: Corrosion Micro/Nano Research (APG)**

Laboratories to induce and examine corrosion at the macro through nano scale.

**Equipment Available:** EIS, CV, accelerated corrosion chambers, Electrochemical AFM, Scanning Kelvin Probe Microscopy, scanning electrochemical microscopy, Hitachi SEM, EDAX, NEC 1.7 Megavolt Ion Accelerator.

**Corrosion of Organic Molecules**

Corrosion of organic molecules to initiate desired breakdown or synthesis. This especially includes the desired breakdown of coatings to monomers to be able to more effectively recycle components for sustainable use of coatings.

**Principal Investigator:** Joseph Labukas      [joseph.p.labukas.civ@mail.mil](mailto:joseph.p.labukas.civ@mail.mil)      (410) 306-4939

**Supporting Facility: Electrochemical Breakdown or Synthesis of Organic Molecules (APG)**

Laboratories to induce and examine corrosion at the macro through nano scale and to characterize organic molecules, including polymers.

**Equipment Available:** Thinky Mixer, Nicolet FTIR, TA Q800 DMAs, DSCs, TGAs, TMAs, AR1000 Rheometer, Hitachi SEM.

**Deformation Processing of Lightweight Materials**

Severe plastic deformation processing of novel materials entails the top-down refinement of coarse-grained microstructures to the ultra-fine and nanoscale regime, resulting in a dramatic improvement in strength without a loss of ductility. Methodologies include equal channel angular extrusion, high-pressure torsion, accumulative roll bonding, friction stir welding, and surface mechanical attrition treatment processing to create material systems with controlled properties such as texture, morphology, and unique or metastable phase chemistries.

**Principal Investigator:** Kevin Doherty      [kevin.j.doherty18.civ@mail.mil](mailto:kevin.j.doherty18.civ@mail.mil)      (410) 306-0871

**Supporting Facility: Severe Plastic Deformation Processing Laboratory (APG)**

**Equipment Available:** Equal Channel Angular Extrusion Press; Plate and Bar Tooling Geometries; Friction Stir Processing Capability.

**Detonation Science**

Investigation of reactive rate for CHNO compounds.

**Principal Investigator:** Kevin McNesby      [Kevin.l.mcnesby.civ@mail.mil](mailto:Kevin.l.mcnesby.civ@mail.mil)      (410) 306 - 1383

**High-Speed Diagnostics (APG)**

Experimental techniques to characterize the reaction of energetic materials when subjected to shock.

**Mentor:** Matt Biss [matthew.m.biss.civ@mail.mil](mailto:matthew.m.biss.civ@mail.mil) (410) 278-3708

**Supporting Facility:** Detonation Science Facility (APG)

Energetic Materials Characterization

**Equipment Available:** high-speed cameras, detonation chambers, Schlieren imaging.

**Disruptive Energetics**

Discovery and inventions of novel energetic materials. Methodologies for discovery include chemical synthesis, mechanochemical synthesis, and high-pressure chemistry and physics. The research area also focuses on investigating novel and efficient energy release concepts.

**Principal Investigator:** Nirupam Trivedi [nirupam.j.trivedi.civ@mail.mil](mailto:nirupam.j.trivedi.civ@mail.mil) (410) 306-3108

**High-Pressure Synthesis (APG)**

Discovery and inventions of novel energetic materials. Methodologies for discovery include mechanochemical synthesis and high-pressure chemistry and physics.

**Principal Investigator:** Jennifer Ciezak-Jenkins [jennifer.a.ciezak-jenkins.civ@mail.mil](mailto:jennifer.a.ciezak-jenkins.civ@mail.mil) (410) 278-6169

**Synthesis of Energetic Materials (APG)**

Research into higher-energy CHNO molecules that offer increased output and are less sensitive than current material.

**Principal Investigator:** Joe Banning [joseph.e.banning2.civ@mail.mil](mailto:joseph.e.banning2.civ@mail.mil) (410) 278-9656

**Supporting Facility:** High-Pressure Synthesis/Laser Diagnostic Lab (APG)

**Equipment Available:** Paris-Edinburg Press, Diamond Anvil Press, various laser equipment.

**Bio-/Neuro-Inspired Sensors and Controls**

Bio-inspired and/or biocompatible microscale sensors, and bio-/neuro-inspired approaches for optimizing the coordination of orthogonal fused-sensing approaches with computation in extremely size-, weight-, and power-constrained, arrayed heterogeneous sensor systems. Envisioned future applications range from autonomous control of micro autonomous systems, to helmet- or textile-integrated physical health monitoring or situational awareness flexible sensor network arrays.

**Principal Investigator:** William Nothwang [william.d.nothwang.civ@mail.mil](mailto:william.d.nothwang.civ@mail.mil) (301) 394-1163



### Supporting Facilities: Sensors and Autonomous Systems Experimental Facility (ALC)

The Sensors and Autonomous Systems Experimental Facility evaluates emerging robotics and sensor systems. Researchers assess autonomous navigation in complex and confined 3D and urban environments using a three-story high urban terrain replica; single platform and collaborative platform simultaneous localization and mapping; collaboration of heterogeneous teams of air and ground platforms, robotic perception, and intelligence; the human-robot interface; platform state estimation; mobility from man-portable-sized systems to the micro-scale; and next-generation see-through-the-wall, ground penetrating radar, IED detection, and unattended ground sensor technologies. The facility includes a fully integrated camera and GPS system for ground truthing; a dark room to simulate cave-like environments; a control room and lab environments for system repair, development, and experimental control; various urban features to include sidewalks, stairs, ramps, variable pitch roofs, various ingress and egress features, balconies, telephone poles, and overhead wiring; a three-feet deep sand bed for characterization of buried devices; and a 120-feet long above-ground computer-controlled trolley.

### Micro Autonomous Systems and Technology (MAST)

Developing enhanced tactical situational awareness in urban and complex terrain by enabling the autonomous operation of a collaborative ensemble of multifunctional and mobile microsystems. Research areas include: Mobility, Control, and Energetics; Communication, Navigation, and Coordination; and Sensing, Perception, and Processing for size and resource constrained autonomous robotic systems and heterogeneous teams of systems.

**Principal Investigator:** Brett Piekarski      [brett.h.piekarski.civ@mail.mil](mailto:brett.h.piekarski.civ@mail.mil)      (301) 394-1263

### Supporting Facilities: Sensors and Autonomous Systems Experimental Facility (ALC)

The Sensors and Autonomous Systems Experimental Facility evaluates emerging robotics and sensor systems. Researchers assess autonomous navigation in complex and confined 3D and urban environments using a three-story high urban terrain replica; single platform and collaborative platform simultaneous localization and mapping; collaboration of heterogeneous teams of air and ground platforms, robotic perception, and intelligence; the human-robot interface; platform state estimation; mobility from man-portable-sized systems to the micro-scale; and next-generation see-through-the-wall, ground penetrating radar, IED detection, and unattended ground sensor technologies. The facility includes a fully integrated camera and GPS system for ground truthing; a dark room to simulate cave-like environments; a control room and lab environments for system repair, development, and experimental control; various urban features to include sidewalks, stairs, ramps, variable pitch roofs, various ingress and egress features, balconies, telephone poles, and overhead wiring; a three-feet deep sand bed for characterization of buried devices; and a 120-feet long above-ground computer-controlled trolley.

## On-Chip Integration of MicroElectroMechanical Systems

This program aims to develop, characterize, and implement energetic materials (propellants, explosives, pyrotechnics) integrated on-chip with electronics, MEMS, or other microfabricated devices and structures which either benefit from the presence of a chemically exothermic energy source, or which enable new modes of initiation, characterization, or control of on-chip energetic reactions. Technical areas of interest include, but are not limited to: materials and methods for integration of energetic materials on-chip (deposition and lithographic patterning, drop casting, 3D printing, etc.), methods and devices for energy conversion to other useful modes (heat, light, pressure, electrical current, etc.), and novel microactuators based on energetic chemical reactions.

Principal Investigator: Chris Morris [christopher.j.morris58.civ@mail.mil](mailto:christopher.j.morris58.civ@mail.mil) (301) 394-0950

### Supporting Facilities: Specialty Electronic Materials and Sensors Cleanroom (SEMASC) (ALC)

This 15,000 gross square feet Class 10 and 100 cleanroom facility houses a comprehensive set of semiconductor fabrication tools—including specialty material deposition, etch, lithography, and thermal—and research characterization systems for the next generation of sensors and electronic devices for the Soldier. These systems enable the fabrication of advanced micro and nanoscale devices using an extremely broad set of device materials including silicon; III-V and IIVI semiconductors; silicon carbide; quartz; lead zirconate titanate (PZT) and aluminum nitride piezoelectrics; many metals and oxides; and graphene and carbon nanotubes. Support applications fabricated with these devices range from bio- and trace gas detection; secure communication (radiofrequency [RF] switches, filters, varactors, and tunable inductors); improvised explosive device (IED) detection (RF switches and filters); mobile sensor platforms for Soldier Intelligence, Surveillance, and Reconnaissance (bio-inspired microflight and terrestrial actuation, ultrasonic motors, bio-inspired sensors); traumatic brain injury (shock sensor, G-switch); RF (resonators, switches); power generation (microturbine, energy harvesting); infrared, ultraviolet, and optical detectors and emitters (imagers, lasers, LEDs); on-chip energetic devices (microthrusters, fuzing); and next-generation flexible, transparent, and high performance electronics and devices based on graphene and other 1D and 2D materials.

## Nanoelectronics and Nanosensors for Army Applications

Explore and exploit layer interactions in stacks of emerging 2D materials to engineer new materials to enable transparent, high performance tunable/multifunctional/conformal electronics.

Principal Investigator: Madan Dubey [madan.dubey.civ@mail.mil](mailto:madan.dubey.civ@mail.mil) (301) 394-1186

### Supporting Facilities: Specialty Electronic Materials and Sensors Cleanroom (SEMASC) (ALC)

This 15,000 gross square feet Class 10 and 100 cleanroom facility houses a comprehensive set of semiconductor fabrication tools—including specialty material deposition, etch, lithography, and thermal—and research characterization systems for the next generation of sensors and electronic devices for the Soldier. These systems enable the fabrication of advanced micro and nanoscale devices using an extremely broad set of device materials including silicon; III-V and IIVI semiconductors; silicon carbide; quartz; lead zirconate titanate (PZT) and aluminum nitride piezoelectrics; many metals and oxides; and graphene and carbon

nanotubes. Support applications fabricated with these devices range from bio- and trace gas detection; secure communication (radiofrequency [RF] switches, filters, varactors, and tunable inductors); improvised explosive device (IED) detection (RF switches and filters); mobile sensor platforms for Soldier Intelligence, Surveillance, and Reconnaissance (bio-inspired microflight and terrestrial actuation, ultrasonic motors, bio-inspired sensors); traumatic brain injury (shock sensor, G-switch); RF (resonators, switches); power generation (microturbine, energy harvesting); infrared, ultraviolet, and optical detectors and emitters (imagers, lasers, LEDs); on-chip energetic devices (microthrusters, fuzing); and next-generation flexible, transparent, and high performance electronics and devices based on graphene and other 1D and 2D materials.

## Growth of III-V-Nitride Materials and Devices

Growth of materials and device structures targeting sources and detectors operating in the spectral region from ultraviolet to terahertz, using 2 Molecular Beam Epitaxy facilities uniquely configured for high-temperature growth (> 1100 C) and with novel sources (Boron, Be, Nd) and a custom metal-organic chemical vapor deposition (MOCVD) system.

<b>Principal Investigators:</b>	Anand Sampath	<a href="mailto:anand.v.sampath.civ@mail.mil">anand.v.sampath.civ@mail.mil</a>	(301) 394-0104
	Michael Wraback	<a href="mailto:michael.wraback.civ@mail.mil">michael.wraback.civ@mail.mil</a>	(301) 394-1459
	Meredith Reed	<a href="mailto:meredith.l.reed.civ@mail.mil">meredith.l.reed.civ@mail.mil</a>	(301) 394-0603

### Novel Transparent Hole Injection Schemes for UV Emitters (ALC)

Investigate the incorporation of novel impurity and polarization-enhanced doping schemes to simultaneously improve hole injection and UV extraction efficiency.

<b>Principal Investigators:</b>	Anand Sampath	<a href="mailto:anand.v.sampath.civ@mail.mil">anand.v.sampath.civ@mail.mil</a>	(301) 394-0104
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### High-Temperature MBE Growth Dynamics (ALC)

Investigate the dynamics of group III adlayer formation, surface mobility, and adsorption, as well as impurity incorporation in III-N material growth at high growth temperatures comparable to those employed for commercial MOCVD processes.

<b>Principal Investigators:</b>	Anand Sampath	<a href="mailto:anand.v.sampath.civ@mail.mil">anand.v.sampath.civ@mail.mil</a>	(301) 394-0104
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### Rare Earth Doped III-Nitride Heterostructure Materials and Devices (ALC)

Investigate the incorporation of rare earth ions into III-Nitride heterostructures and diodes and the impact of large tunable electric fields on the optical properties of the rare earth ions.

<b>Principal Investigators:</b>	Anand Sampath	<a href="mailto:anand.v.sampath.civ@mail.mil">anand.v.sampath.civ@mail.mil</a>	(301) 394-0104
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## Wide Band Gap Power Device Reliability

Wide band gap power devices are key components for next generation military sub-systems. However, the reliability of these devices has not been well established and the harsh operating conditions that will be typical in military applications are expected to introduce failure modes that are not critical to the commercial market. Therefore, investigation and modeling of key failure mechanisms in emerging GaN and SiC power devices is

needed. Research to investigate key degradation mechanisms and failure modes of emerging GaN power semiconductor devices and develop improved test methods that ensure reliable device operation.

**Principal Investigator:** Aivars Lelis [aivars.j.lelis.civ@mail.mil](mailto:aivars.j.lelis.civ@mail.mil) (301) 394-5426

#### Supporting Facility: Wide Band Gap Electronics Characterization Laboratory (ALC)

Laboratory supports static and dynamic power device evaluation and semiconductor/dielectric interface characterization to study reliability physics.

**Equipment Available:** Semiconductor parameter analyzers, curve tracers, high voltage/high power SMUs, pulse measurement units for fast I-V, electromagnet for hall effect, ovens and heaters for high temperature testing, semi-automatic and manual probe stations

### GaN High Power Electronic Devices

Design, fabricate and test GaN/AlGaIn based high power electronic devices. Work on improving the crystalline quality and reducing the background carrier concentration of the semiconductor material, as well as improve the quality of the dielectric used in field plates and for passivating the surface. Develop ion implantation activation processes for junction termination.

**Principal Investigator:** Kenneth Jones [kenneth.a.jones162.civ@mail.mil](mailto:kenneth.a.jones162.civ@mail.mil) (301) 394-2005

#### Supporting Facilities

Complete clean room for fabricating the devices and automated device testing facility to characterize them. Measure the electrical properties of the semiconductor material with Hall effect, C-V profiling, contactless mobility measurements, and DLTS system. Examine the structure of the material with double crystal x-ray diffraction, CL and TEM, and the surface morphology with AFM.

### AlGaIn Beta(photo)voltaic Batteries

Design, fabricate and test GaN/AlGaIn based betavoltaic and betaphotovoltaic devices. In betavoltaics work on improving the ability to capture excited electrons and holes before they recombine by creating a wider depletion layer and associated electric field using polarization effects. In betaphotovoltaics work on improving the efficiency of phosphors excited by beta particles and matching the AlGaIn energy gap to their output spectra. Develop devices for both  $^3\text{H}$  and  $^{63}\text{Ni}$ .

**Principal Investigators:** Ken Jones [kenneth.a.jones162.civ@mail.mil](mailto:kenneth.a.jones162.civ@mail.mil) (301) 394-2005  
 Jeff Carroll [james.j.carroll99.civ@mail.mil](mailto:james.j.carroll99.civ@mail.mil) (301) 394-0243

#### Supporting Facilities

Complete clean room for fabricating the devices and automated device testing facility to characterize them. Test the device response with *i*-V, photo *i*-V, and EBIC. Measure the electrical properties of the semiconductor material with Hall effect, C-V profiling, contactless mobility measurements, and DLTS system. Examine the structure of the material with double crystal x-ray diffraction, CL and TEM, and the surface morphology with AFM. Nuclear facilities

## Microfluidics for Energy Conversion

Microfluidics play an important role in shrinking energy conversion devices. Current thrusts are focused on electrospray fuel injection, direct fuel vaporization in micro-channels, and micro-channel heat recuperation for monolithic integration with combustion heat sources. Design, modeling, and microfabrication of electrospray and microchannel devices, and experimental characterization of the devices for multiplexed electrospray and microchannel liquid vaporization, respectively, of JP-8 fuel. Investigating methods to electrospray JP-8 without additional electrostatic additives, and implement the methods into the compact, multiplexed electrospray devices.

Principal Investigator: C. Mike Waits      [christopher.m.waits.civ@mail.mil](mailto:christopher.m.waits.civ@mail.mil)

(301) 394-0057

### Supporting Facility

Dedicated lab space contains extensive capability for liquid spray characterization and micro-channel visualization and measurements. Extensive use of the ARL clean room and machine shop facilities are used to make devices. Numerical simulation and CAD software are available locally as well as on the ARL supercomputer and include access numerous FEA and CFD packages and mathematical software.

**Equipment Available:** Phase Doppler Particle Analyzer, high voltage power supplies, low flow rate VICI liquid gear pump, optical inspection equipment, high speed camera, DAQ.

## Microcombustion

Pursuit of micro-combustion technology focuses on developing highly efficient and scalable heat sources using JP-8 and other fuel alternatives. These heat sources can be combined with energy conversion technology to develop compact, high density power sources or serve as an efficient heat source for applications like cooking stoves. Developing new approaches to integrate combustion, heat recuperation and liquid vaporization that enable scaling combustion based power sources for extremely compact platforms. Investigation of improved experimental techniques for micro-combustion and improved fast numerical techniques to combine thermal, mass transport, and reaction (surface and gas-phase) modeling.

Principal Investigator: C. Mike Waits      [christopher.m.waits.civ@mail.mil](mailto:christopher.m.waits.civ@mail.mil)

(301) 394-0057

### Supporting Facility

Dedicated lab space provides fume hoods for micro-reactor characterization and equipment for catalyst preparation. Catalytic Conversion Laboratory also utilized for chemical analysis. Extensive use of the ARL clean room and machine shop facilities are used to make devices. Numerical simulation and CAD software are available locally as well as on the ARL supercomputer and include access numerous FEA and CFD packages and mathematical software.

**Equipment Available:** LabVIEW controlled micro-reactors with flow, visual, and thermal characterization equipment. High temperature oven.



## Thermal-to-electric Energy Conversion

Electrothermal characterization of thin-films, measurements of radiative heat from gray-body or selective emitters, setting up and running experiments that characterize thermal-to-electric conversion components and breadboard systems, and analyzing collected data. Investigate the design, materials, and preferred approach to integrate high spectral efficiency selective emitters with micro-combustors and/or meso-scale combustors

**Principal Investigator:** C. Mike Waits      [christopher.m.waits.civ@mail.mil](mailto:christopher.m.waits.civ@mail.mil)      (301) 394-0057

### Supporting Facility

Dedicated lab space provides fume hoods for micro-reactor characterization and equipment for catalyst preparation. Catalytic Conversion Laboratory also utilized for chemical analysis. Extensive use of the ARL cleanroom and machine shop facilities are used to make devices. Numerical simulation and CAD software are available locally as well as on the ARL supercomputer and include access numerous FEA and CFD packages and mathematical software.

**Equipment Available** Phase Doppler Particle Analyzer, high voltage power supplies, low flow rate VICI liquid gear pump, optical inspection equipment, high speed camera, DAQ

## Wireless Power

Wireless power transfer is attractive for electronics at power levels ranging from milliwatts for body health monitoring up to kilowatts for vehicle charging, and at all levels in between. However, implementations of wireless power solutions are commonly disrupted by poor efficiency and poor adaptability in dynamic environments. New materials, circuits, and topologies are required to provide solutions that are better than the legacy power cord. For example, soldiers are being outfitted with an ever increasing number of electronic gadgets, each of which has unique battery requirements. An inductively coupled wireless power solution is required to distribute power from a single, centrally-worn battery source to numerous electronic devices at length scales up to 1 m.

**Principal Investigator:** Chris Meyer      [christopher.d.meyer1.civ@mail.mil](mailto:christopher.d.meyer1.civ@mail.mil)      301-394-4286

### Supporting Facility

Power passives fabrication laboratory - Integrated power passives require low loss materials with nano- and micro-scale feature resolutions. Electrochemical plating chemistries and power supplies for depositing copper, nickel, gold, and tin on wafer and chip scale devices. Piezoelectrically driven ink jet deposition of custom nanoparticle solutions. Vacuum degasification.

## Energy Harvesting

Energy harvesting could enable indefinite-length missions in hostile environments, but any solutions must carefully balance stringent requirements in power levels, metabolic cost, comfort, durability, and ease of use. A systems-level model is required to guide the development of new energy harvesting technologies that can simultaneously handle the breadth of possible use cases while capturing the intricacies of power management and human behavior.

**Principal Investigator:** Chris Meyer

[christopher.d.meyer1.civ@mail.mil](mailto:christopher.d.meyer1.civ@mail.mil)

301-394-4286

### Supporting Facility

Power passives fabrication laboratory - Integrated power passives require low loss materials with nano- and micro-scale feature resolutions. Electrochemical plating chemistries and power supplies for depositing copper, nickel, gold, and tin on wafer and chip scale devices. Piezoelectrically driven ink jet deposition of custom nanoparticle solutions. Vacuum degasification.

## Micro-scale / MEMS Power Components

High frequency power conversion will enable fully integrated power supplies on a chip. Such power supplies are attractive for lightweight and wearable power management and distribution networks, power management for portable electronics, miniature robotic platforms, and high efficiency antenna arrays requiring varying voltages at each element. This research area focuses on developing new, high-frequency components, enabled by MEMS and microfabrication, with low-profile and high efficiencies. The modeling fabrication, and characterization of miniature power converter circuits and topologies for power supplies on chip leverages MEMS and micromachined power passive devices.

**Principal Investigator:** Sarah Bedair

[sarah.s.bedair.civ@mail.mil](mailto:sarah.s.bedair.civ@mail.mil)

301-394-0021

### Supporting Facility

Power passives fabrication laboratory - Integrated power passives require low loss materials with nano- and micro-scale feature resolutions. Electrochemical plating chemistries and power supplies for depositing copper, nickel, gold, and tin on wafer and chip scale devices. Piezoelectrically driven ink jet deposition of custom nanoparticle solutions. Vacuum degasification.

## Heterogeneous Device Integration

Investigation of a new 3D High Density Integration Process (3D-HIP) to create 3D stacked electronic systems compatible with diverse device technologies, substrates, and materials. 3D-HIP focuses on wafer-level packaging of heterogeneous devices with released MEMS components. Investigation of the modeling and microfabrication of MEMS power passive devices, development of fabrication processes for new power

materials and devices, and development of high-efficiency materials (e.g. magnetics and dielectrics) and MEMS / micro-machined devices.

**Principal Investigator:** Sarah Bedair

[sarah.s.bedair.civ@mail.mil](mailto:sarah.s.bedair.civ@mail.mil)

301-394-0021

### Supporting Facility

**Power Passives Fabrication Laboratory** - Integrated power passives require low loss materials with nano- and micro-scale feature resolutions. Electrochemical plating chemistries and power supplies for depositing copper, nickel, gold, and tin on wafer and chip scale devices. Piezoelectrically driven ink jet deposition of custom nanoparticle solutions. Vacuum degasification.

## Catalysis and Fuel Chemistry

Our objective is to rationally design new durable catalyst materials for fuel conversion of JP-8 fuel and its surrogates. This program features materials-by-design approach using multiscale modeling with advanced experimental techniques in synthesis and reaction kinetic studies. Investigation of sulfur tolerant JP-8 combustion catalysts include catalyst synthesis, materials characterization and catalyst evaluation in bench top prototype reactors. Investigation of deactivation of JP-8 combustion catalyst using experiments and kinetic modeling to elucidate the mechanism of catalyst deactivation by coke and sulfur impurities in the catalytic oxidation processes.

**Principal Investigator:** Ivan Lee

[ivan.c.lee2.civ@mail.mil](mailto:ivan.c.lee2.civ@mail.mil)

(301) 394-0292

### Supporting Facility

The Catalytic Fuel Conversion Facility allows catalyst materials preparation, characterization and evaluation.

**Equipment Available:** The facility is equipped with LabVIEW controlled reactors, analytical tools such as micro-GC and mass spectrometer, a glove box, a Bruker Vertex 70 FTIR spectrometer with in-situ time-resolved capability, as well as a Quantachrome physisorption-chemisorption analyzer. Other on-site capabilities include X-ray diffraction and electron microscopy.

## Fuel Processing

Fundamental and applied research on reforming fuels for use in fuel cells including sulfur mitigation.

**Principal Investigator:** Deryn Chu

[deryn.d.chu.civ@mail.mil](mailto:deryn.d.chu.civ@mail.mil)

(301) 394-0308

### Supporting Facility

Fuel cell/fuel reforming lab. 24/7 operation with analytical characterization. gc/ms, S analyzer, electrochemical equipment

**Alkaline Fuel Cells (ALC)**

Fundamental research and development projects on alkaline membrane fuel cells, involving fuel cell component development, characterizations, and fuel cell tests.

**Principal Investigator:** Xiaoming Ren      [xiaoming.ren.civ@mail.mil](mailto:xiaoming.ren.civ@mail.mil)      (301) 394-0379

**Supporting Facility**

Fuel cell test stations, Impedance analyzer and other electrochemical test equipments, fume hood for electrochemical catalyst synthesis and membrane electrode assembly preparation. Polymer electrolyte membrane and catalysts characterization setups.

**Computational Modeling of Alkaline Fuel Cells (ALC)**

This area involves the modeling and simulation of anion exchange membrane materials and interfaces relevant to the alkaline membrane fuel cell. Research includes the development and application of models related to transport and interfacial phenomena in the corresponding materials, components, and systems. Of particular interest are efforts related to the transport and stability of the alkaline membrane materials and interfacial processes associated with the electrochemical (ionomer/catalyst/reactant) interface.

**Principal Investigator:** Kyle Grew      [kyle.n.grew.civ@mail.mil](mailto:kyle.n.grew.civ@mail.mil)      (301)394-3561

**Advanced Battery Chemistries**

Fundamental and applied research on advanced battery materials.

**Principal Investigator:** Cynthia Lundgren      [cynthia.a.lundgren2.civ@mail.mil](mailto:cynthia.a.lundgren2.civ@mail.mil)      (301) 394-2541

**Electrolyte Additives for Advanced Battery Chemistries (ALC)**

Breaking out the limit on energy densities of Li ion batteries, advanced (or “beyond Li ion”) battery chemistries pursues the ability of accommodating Li<sup>+</sup> or other guest cations (Na<sup>+</sup>, Mg<sup>2+</sup>) by adopting non-intercalation type electrode materials, whose drastic morphologic change presents unprecedented challenge to electrolyte and interphases. This research opportunity aims to develop and understand interphasial chemistry of electrolytes or additives for “Beyond Li Ion Chemistries” using Si anodes, Na and Mg electrolytes, S and O<sub>2</sub> cathodes.

**Principal Investigator:** Kang Xu      [conrad.k.xu.civ@mail.mil](mailto:conrad.k.xu.civ@mail.mil)      (301) 394-0321

**Dual Intercalation Batteries (ALC)**

There are project areas including the investigation of new electrolytes and electrolyte additives that improve the performance of dual-graphite cells for grid storage applications, fundamental studies to characterize the material property changes in anion intercalated graphite, and applied research on full dual-graphite cell performance.

**Principal Investigator:** Jeffrey Read      [jeffrey.a.read4.civ@mail.mil](mailto:jeffrey.a.read4.civ@mail.mil)      (301) 394-0313

**Solid Li-Ion Conducting Membranes (ALC)**

Investigation of new solid Li-ion conducting materials and their processing into dense membranes and structural, physical and electrochemical characterization at room and elevated temperature. Evaluation of the chemical and electrochemical stability of solid Li-ion conductors based on the garnet structure with various potential anode (e.g., lithium) and cathode (e.g., sulfur) materials at room and elevated temperature.

**Principal Investigator:** Jeff Wolfenstine      [jeffrey.b.wolfenstine.civ@mail.mil](mailto:jeffrey.b.wolfenstine.civ@mail.mil)      (301) 394-0317

**Li Ion Batteries (ALC)**

Fundamental and applied research on developing higher energy density safe Li-ion batteries, which are to be achieved through the use of high voltage and/or high capacity intercalation type compounds as cathode and carbonaceous materials with or without Li alloys such as LiSix alloys as anode, than the state-of-the-art Li-ion batteries. Developments of structurally stable cathodes are urgently needed. Meanwhile, electrolytes that are compatible with both the new cathodes and anodes are also in urgent need.

**Principal Investigator:** Richard Jow      [t.r.jow.civ@mail.mil](mailto:t.r.jow.civ@mail.mil)      (301) 394-0340

**Solid-Electrolyte Interphase (SEI) Characterization (ALC)**

**Principal Investigator:** Arthur Von Cresce      [Arthur.v.cresce.civ@mail.mil](mailto:Arthur.v.cresce.civ@mail.mil)      (301) 394-1967

**Computational Modeling of Battery Materials (ALC)**

Computational modeling of battery materials from quantum to mesoscale levels with a focus on understanding structural and transport properties of battery electrolytes and SEI components in bulk and at the interfaces. Modeling of electrolyte oxidation and reduction stability, prediction of electrolyte decomposition reactions at electrodes.

**Principal Investigator:** Oleg Borodin      [oleg.a.borodin.civ@mail.mil](mailto:oleg.a.borodin.civ@mail.mil)      (301) 394-0066

**Supporting Facility**

Dedicated lab space (dry room, fume hoods, glove boxes) and equipment for processing (e.g., high energy mixers/mills, high temperature inert atmosphere furnaces) and characterization (e.g., thermal analysis set-up, x-ray diffraction unit, electron microscopy facility, in-situ atomic force microscope, high frequency impedance analyzers, potentiostats/galvanostats).

**Polymeric Dielectrics for Next Generation Capacitors**

Fundamental and applied research on advanced high energy density polymeric dielectrics and capacitors.

**Principal Investigators:** Janet Ho      [janet.s.ho.civ@mail.mil](mailto:janet.s.ho.civ@mail.mil)      (301) 394-0051  
 Richard Jow      [t.r.jow.civ@mail.mil](mailto:t.r.jow.civ@mail.mil)      (301) 394-0340



**Dielectric Performance (ALC)**

Army needs to go beyond the present state-of-the-art poly(propylene) and poly(ethylene terephthalate) for pulse power and power conditioning applications. The immediate research opportunity aims to modify existing commercially-available capacitor-grade polymers either by surface treatments or polymer structure alteration in solid state to improve dielectric performance, through an interconnected feedback between experimental research and first-principle computational modeling such as density-functional theory. The future research will leverage results from the present MURI "Rational Design of Advanced Polymer Capacitor Dielectrics" sponsored by Office of Naval Research to tailor-make new materials.

**Principal Investigators:** Janet Ho [janet.s.ho.civ@mail.mil](mailto:janet.s.ho.civ@mail.mil) (301) 394-0051  
Richard Jow [t.r.jow.civ@mail.mil](mailto:t.r.jow.civ@mail.mil) (301) 394-0340

**Higher Energy Density Polymeric Dielectrics (ALC)**

The Army is in need of higher energy density film capacitors than the state-of-the-art capacitors made of biaxially oriented polypropylene (BOPP) for high pulse power and continuous power condition applications. To achieve this goal, higher energy density polymeric dielectrics that can withstand high field under fast charge/discharge conditions and high temperatures at around or above 150 oC with low loss are urgently needed. Research areas of interest include the following. Investigate breakdown mechanism in relation to morphology (amorphous vs. crystalline polymers), processing condition (melt extrusion vs. solution cast) and polymer structures (high molecular weight, backbone and functional groups) of advanced polymers such as high temperature polycarbonate and fluoropolymers. Develop and investigate techniques for improved polymer metal interfacial bonding, polymer/blocking layer/metal interfacial bonding for high current capability and self-clearing under breakdown conditions.

**Principal Investigators:** Janet Ho [janet.s.ho.civ@mail.mil](mailto:janet.s.ho.civ@mail.mil) (301) 394-0051  
Richard Jow [t.r.jow.civ@mail.mil](mailto:t.r.jow.civ@mail.mil) (301) 394-0340

**Power Control & Distribution**

Investigate circuit breaker architectures and semiconductor device performance to improve the performance of 1200V class solid state circuit breakers. Also design sensing and supporting control electronics.

**Principal Investigator:** Damian Urciuoli [damian.p.urciuoli.civ@mail.mil](mailto:damian.p.urciuoli.civ@mail.mil) (301) 394-3240

**Supporting Facility**

Pulse power testbeds, simulation software, circuit design software, data acquisition equipment.

**Extreme Semiconductor Switching - Design, Evaluation, Simulation, Analysis (ALC)**

Research supporting the Army's extreme switching needs for high-power systems. Includes surveying and analyzing Army application needs, designing appropriate evaluation circuitry and techniques, understanding mechanics and safety of working with high power, evaluating and analyzing components, collaborating with external research partners, developing models of devices and applications, and creating a better understanding of semiconductor physics under extreme electrical conditions.

**Principal Investigator:** Skip Scozzie [charles.j.scozzie.civ@mail.mil](mailto:charles.j.scozzie.civ@mail.mil) (301) 394-5211

## Supporting Facility

The Power Conditioning Lab is designated for high-voltage, high-current, and high-energy circuits and component evaluations at the several kilo-volt, kilo-amp, and kilo-joule levels. List of equipment: high-voltage power supplies, passive components capable of high-energy storage and dissipation, curve tracers, oscilloscopes, probes, a large oven, and safe procedures and barriers in place for high-power work.

### Semiconductor Components and Simulations (ALC)

Investigation of Army extreme switching needs and evaluation of semiconductor components to their maximum capabilities at high voltage, high current, varying pulse widths, varying duty cycle, across wide temperature ranges. Includes circuit design, measurement technique, data analysis, and study of semiconductor physics. Implement models and active simulations of existing or future semiconductor components, and develop an understanding of semiconductor physics and how to incorporate laboratory measurements with simulations.

#### Principal Investigators:

Heather O'Brien	<a href="mailto:heather.k.obrien.civ@mail.mil">heather.k.obrien.civ@mail.mil</a>	(301) 394-5545
Aderinto Ogunniyi	<a href="mailto:aderinto.a.ogunniyi.civ@mail.mil">aderinto.a.ogunniyi.civ@mail.mil</a>	(301)394-0058

## High Power Semiconductor Devices

Design, fabricate and test GaN/AlGaN based high power electronic devices. Work on improving the crystalline quality and reducing the background carrier concentration of the semiconductor material, as well as improve the quality of the dielectric used in field plates and for passivating the surface. Develop ion implantation activation processes for junction termination.

Principal Investigator: Ken Jones	<a href="mailto:kenneth.a.jones162.civ@mail.mil">kenneth.a.jones162.civ@mail.mil</a>	(301) 394-2005
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## Supporting Facility

ARL Clean room, Power Electronics Measurement Lab, Material Characterization Labs. The ARL Clean room has the facilities for fabricating all types of semiconductor devices. Devices are automatically probed in the measurements lab; those selected for detailed meas are measured at different temp and power settings. Carrier concentrations & mobilities are measured & defect states are probed via DLTS. Clean room lithography, etching, metallization, & dielectric deposition capabilities. Automatic semiconductor probe stations with variable temperature capabilities. Hall effect, contactless conductivity, and DLTS.

## High Voltage Power Electronics

Develop components and materials that will enable the next-generation of high-power military electronics. Investigate system, component, and materials implications of high voltage (>50kV) power electronics.

Principal Investigator: Wes Tipton	<a href="mailto:wes.tipton@us.army.mil">wes.tipton@us.army.mil</a>	(301) 394-5209
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### Supporting Facility

The ARL Power Conditioning Laboratory is equipped to design, fabricate, and evaluate power conversion systems operating at 200 kW and 50 kV. Available resources include voltage power sources up to 150kV, electronics diagnostic instruments.

### Wide Band Gap Semiconductor Packaging Materials and Technologies (ALC)

Investigate novel packaging materials and technologies for high temperature and high voltage power electronics applications to enable the next-generation of high-power military electronics.

**Principal Investigator:** Dimeji Ibitayo [oladimeji.o.ibitayo.civ@mail.mil](mailto:oladimeji.o.ibitayo.civ@mail.mil) (301) 394-5514

### Supporting Facility

The ARL Power Semiconductor Packaging Laboratory is designated to develop and evaluate advanced packaging technologies and processes that enable higher performance and reliability of electrical power conversion in Army systems.

### 3kW to 300kW AC/DC Microgrids Hardware/Software/Hardware-Software Control

Advance technologies for efficient utilization of all available energy and to provide intelligent distribution of power. Technologies to encompass simple to use power distribution hardware; power line sensing that can learn and apply load and source signatures; prognostics and diagnostics for loads and sources; lightweight and compact multi function power conversion and distribution systems and compact energy dense energy storage systems. Technologies to encompass distributed control of power distribution systems and the estimation and prediction of solar flux on PV arrays. Technologies to encompass cognitive systems for improved and automated Data-to-Decision; utilization of learned behaviors from previous operations; Software that can rapidly adapt to grid operation while learning system behavior; use of tangible and intangible energy costs in the prioritization of demands; trainable systems and the utilization of learned behaviors from previous operations.

**Principal Investigators:** Bruce Geil [bruce.r.geil@mail.mil](mailto:bruce.r.geil@mail.mil) (301) 394-3190  
Donald Porschet [donald.h.porschet.civ@mail.mil](mailto:donald.h.porschet.civ@mail.mil) (301) 394-5528

### Tactical Energy Network Research Facility (TENRF) Command, Control, Communications, Computer and Intelligence (C4I) (ALC)

Implement novel AC/DC Micro-grid related command, control, communications, and computer and intelligence structures in a controlled environment.

**Principal Investigators:** Donald Porschet [donald.h.porschet.civ@mail.mil](mailto:donald.h.porschet.civ@mail.mil) (301) 394-5528  
Damian Urciuoli [damian.p.urciuoli.civ@mail.mil](mailto:damian.p.urciuoli.civ@mail.mil) (301) 394-3240  
Wes Tipton [wes.tipton@us.army.mil](mailto:wes.tipton@us.army.mil) (301) 394-5209

## Supporting Facility

Tactical Energy Network Research Facility (TENRF) is intended to serve as a State-of-the-Art facility for testing 6.1 - 6.5 micro-grid focused components in a controlled setting with highly variable and configurable AC/DC sources and loads. Available resources include both 18 kVA & 36 kVA variable frequency/voltage power sources, 20 kW 208 VAC/3 ph generator, PhotoVoltaic Simulator, 10 kW Dynamometer, Dynamic AC/DC loads and a Real Time Digital Simulator.

## 3kW to 300kW AC/DC Microgrids Modeling and Simulation

Develop modeling and simulation software and architecture analysis for tactical energy networks.

**Principal Investigator:** Ed Shaffer      [edward.c.shaffer.civ@mail.mil](mailto:edward.c.shaffer.civ@mail.mil)      (301) 394-2002

### Modeling and Simulation for Novel Microgrid Architectures and Technologies (ALC)

Develop novel simulation platform for modeling and analysis of microgrid power system architectures. Develop library of tools for optimized design and simulation of microgrid and power electronics components integration, and various energy management systems.

**Principal Investigator:** Ed Shaffer      [edward.c.shaffer.civ@mail.mil](mailto:edward.c.shaffer.civ@mail.mil)      (301) 394-2002

## Supporting Facility

Modeling and simulation effort and architectural analysis for microgrids and microgrid components integration. Access to numerous software packages Matlab, LabView, Simulink.

## Microscale Thermal Measurement -Time Domain Thermal Reflectance Measurement of Materials and Interfaces

Time domain thermal reflectance is a technique capable of measuring heat transfer from picosecond to microsecond timescales. The project will focus on improving the fidelity of ARL's TDTR capability, followed by thermal characterization of electronic materials and solid-solid and solid-liquid thermal interfaces. This will include extension of the technique to measure long-time constant transient phenomena. Solid state materials, low melting temperature metals, and other materials are promising phase change materials with limited knowledge of critical material data. Measuring and cataloguing this data is a critical step to enabling future system design.

**Principal Investigator:** Nick Jankowski      [nicholas.r.jankowski.civ@mail.mil](mailto:nicholas.r.jankowski.civ@mail.mil)      (301) 394-2337

### Boiling Heat Transfer -Behavior of Pool Boiling on Micro-scale Heat Sources (ALC)

The behavior of a static boiling system in the presence of heat sources smaller than critical bubble and wetting length scales is poorly understood. Enhanced modeling and measurement of such systems should result in higher fidelity boiling models which can improve predictability of two-phase heat transfer systems.

**Principal Investigator:** Nick Jankowski      [nicholas.r.jankowski.civ@mail.mil](mailto:nicholas.r.jankowski.civ@mail.mil)      (301) 394-2337

**Boiling Heat transfer - Binary Fluid Behavior in Two-phase Flows (ALC)**

Many engineering fluids are multi-constituent liquids. These liquids will have unique behavior under boiling conditions, and their impact when used in heat transfer applications is largely unknown. There is interest in better understanding the behavior of binary liquids under boiling conditions, the system level impacts of their use, and whether components/systems can be designed to take advantages of their unique behavior.

**Principal Investigator:** Nick Jankowski      [nicholas.r.jankowski.civ@mail.mil](mailto:nicholas.r.jankowski.civ@mail.mil)      (301) 394-2337

**Phase Change Materials - Supercooling Reduction in High Performance Phase Change Materials (ALC)**

Promising high performance phase change materials suffer a temperature-phase hysteresis that could potentially lead to critical failure in a thermal protection system. The literature contains some reference to mechanical, chemical, and electrical (or electrochemical) mitigation, but little fundamental understanding of the mechanism. Focusing on methods of mechanical or electrical supercooling reduction would avoid material modification, and provide insight into nucleation behavior. Project would model nucleation potential under various stimuli, and experimentally characterize the effects.

**Principal Investigator:** Nick Jankowski      [nicholas.r.jankowski.civ@mail.mil](mailto:nicholas.r.jankowski.civ@mail.mil)      (301) 394-2337

**Supporting Facility**

Thermal Sciences laboratory has dedicated lab space containing single and two-phase flow loops compatible with water and dielectric fluids at high power and temperatures. Extensive use of the ARL clean room and machine shop facilities are used to make devices. Numerical simulation and CAD software are available locally as well as on the ARL supercomputer and include access numerous FEA and CFD packages and mathematical software. Boiling flow loop test stand. Condensation enhancement test stand. IR cameras. High-speed video camera. Thermal control and data acquisition hardware/software. Custom thermal interface material test stand.

**Solar Fuels**

Fundamental research on alternative routes to fuels to include plasmonic catalysis, photosynthesis and direct photoelectrolysis. The development of on-site fuel generation requires disruptive technologies for photocatalytic applications. Plasmonics and metamaterials offer a great potential to increase reaction rates and solar absorption cross-sections for photoelectrochemical reactions. Nanostructured arrays are intricately designed to enhance and manipulate electric fields which impart energy to the desired reactions, such as water splitting and synthesis of carbon based fuels.

**Principal Investigator:** Cynthia Lundgren      [cynthia.a.lundgren2.civ@mail.mil](mailto:cynthia.a.lundgren2.civ@mail.mil)      (301) 394-2541

**Alternative Routes to Fuel - Effect of EM Radiation and Metamaterials on Catalysis (ALC)**

Fundamental research on the use of different types of EM radiation and metamaterials and their effects on catalysis for the purpose of making fuels out of readily available resources. Photosynthesis, artificial photosynthesis, direct photoelectrolysis with wide bandgap semiconductors, plasmonically enhanced electrocatalysis, effects of electromagnetic fields on catalysis.

**Principal Investigator:** Cynthia Lundgren      [cynthia.a.lundgren2.civ@mail.mil](mailto:cynthia.a.lundgren2.civ@mail.mil)      (301) 394-2541



## Supporting Facilities

Several facilities at ALC support this research area. The Electrochemistry lab uses potentiostats and light sources for solar simulation purposes along with optical elements for electrochemical characterization. ARL clean room tools are used for sample fabrication. Modeling techniques used for directed sample design.

## Ultra-energetic Materials

Radioisotopes store ~ 100,000× times the energy density of chemical batteries, and many release that energy on a time scale of decades or longer. Practical packaging of radioisotopes like tritium or  $^{63}\text{Ni}$ , and improved energy conversion techniques may enable drop-and-forget sensor networks for persistent battlespace awareness. An ability to control the rate and mechanism of energy release may enhance this or other applications, based on manipulation of nuclear isomers. These are excited quantum states of atomic nuclei with very long half-lives, due to their large angular momenta, that can also exceed decades: in the most extreme case the isomer of  $^{180}\text{Ta}$  lives longer than  $10^{16}$  years, while its ground state half-life is 8.2 hours. Nuclei can, therefore, be “switched” between long-lived (energy storage) and short-lived (energy release) states upon demand, using reactions to access pathways via higher-lying levels. This process has been demonstrated experimentally for five isomers, with the most recent being the switching of  $^{108\text{m}}\text{Ag}$  at ARL. Practical use of isomers will require better understanding of the physics of switching, production of isomers, matching of switching devices and efficient energy conversion. The ARL research program in this field represents a unique effort.

**Principal Investigators:** James J. Carroll      [james.j.carroll99.civ@mail.mil](mailto:james.j.carroll99.civ@mail.mil)      (301) 394-0243  
 Marc Litz      [marc.s.litz.civ@mail.mil](mailto:marc.s.litz.civ@mail.mil)      (301) 394-5556

## Radiation Detection and Effects on Materials; Nuclear Physics (ALC)

Existing theory is not sufficient to predict the paths for depletion of energy from excited nuclear states (isomers) to ground states or decaying isotopes. Basic and applied research investigating nuclear structure is required in order to better understand both stimulating and depleting excited states within the nucleus. Both energy storage(stimulated) and energy-on-demand(depleted) conversion paths are studied. Detailed characterization of radiation detectors, radiation effects in materials and measurement of fundamental properties of nuclear reactions and nuclear structure are pursued.

**Principal Investigator:** James J. Carroll      [james.j.carroll99.civ@mail.mil](mailto:james.j.carroll99.civ@mail.mil)      (301) 394-0243

## Radioisotope Battery Development (ALC)

Applied research focuses on energy conversion from decaying isotopes for utilization as a power source. Energy conversion efficiencies of phosphors under stimulation of keV energy electrons from beta-decay are studied. Bulk material properties and fabrication dependent surface properties of photovoltaic energy conversion is evaluated with specific interest in minimizing dark currents under low-light conditions. Nuclear scattering and transport processes in semiconductors are modeled with the goal of designing higher efficiency direct energy conversion wide band-gap materials.

**Principal Investigator:** Marc Litz      [marc.s.litz.civ@mail.mil](mailto:marc.s.litz.civ@mail.mil)      (301) 394-5556

### Supporting Facility

X-ray Effects Laboratory (XEL) for studies on radiation detection and radiation effects on materials; nuclear physics studies. Extensive instrumentation for dosimetry and spectroscopy of radiation, and ability to produce electron and photon beams with energies in the 1 - 6 MeV range. 1 MeV/2 MeV electron linear accelerator. 6 MeV electron linear accelerator. Radiochromic film dosimeter system. Extensive suite of alpha, beta and gamma-ray detectors, including single-crystal and Clover HPGe detectors, with associated analog and digital-processing instrumentation. Tritium laboratory for development and testing of isotope battery configurations.

### Superconducting Materials Investigation

High Temperature YBCO-based Superconductors (HTS) have high potential for a wide range of applications. The objective is to increase the critical current density of YBCO superconductors by pinning enhancement and precise control of energy transfer and mass transfer by MOCVD deposition. Basic and applied research on materials growth of YBCO with process parameter optimization, superconductivity measurements and characterization, and performance evaluation in certain aspects. Additional phenomena such as persistent current relaxation and normal zone propagation will be studied, as well as potential application of YBCO in sensor development.

**Principal Investigator:** Charles Rong    [charles.c.rong.civ@mail.mil](mailto:charles.c.rong.civ@mail.mil)    (301) 394-0286

### Supporting Facility

Superconductor laboratory at ALC for MOCVD YBCO deposition and persistent current measurement at 77 K.

### Nuclear Batteries

Design, fabricate and test GaN/AlGaN based betavoltaic and betaphotovoltaic devices. In betavoltaics work on improving the ability to capture excited electrons and holes before they recombine by creating a wider depletion layer and associated electric field using polarization effects. In betaphotovoltaics work on improving the efficiency of phosphors excited by beta particles and matching the AlGaN energy gap to their output spectra. Develop devices for both <sup>3</sup>H and <sup>63</sup>Ni.

**Principal Investigators:** Ken Jones    [kenneth.a.jones162.civ@mail.mil](mailto:kenneth.a.jones162.civ@mail.mil)    (301) 394-2005  
James J. Carroll    [james.j.carroll99.civ@mail.mil](mailto:james.j.carroll99.civ@mail.mil)    (301) 394-0243

### Supporting Facilities (ALC)

ARL Cleanroom, Power Electronics Measurement Lab, Material Characterization Labs. The ARL cleanroom has the facilities for fabricating all types of semiconductor devices. Electronics measurements lab has the ability to measure the IV and photo-IV properties as well as make EBIC measurements. Cleanroom lithography, etching, metallization & dielectric deposition capabilities. Semiconductor probe stations can measure IV and photo-IV. Modified SEM can make EBIC and CL measurements.

## High-Performing Bio-Based Polymers

Petroleum-based polymers are not sustainable. Lignin, cellulose, carbohydrates, triglycerides, other renewable feedstocks, and green chemistry represent a sustainable source to generate monomers and polymers; development can result in innovation, resulting in chemical and material advances that would not otherwise come to fruition. Thus, we are developing novel polymers from renewable resources to replace petroleum-derived high-performance polymers for Army applications from fabric for uniforms to high-strength fibers for armor. Research focuses on chemical synthesis of monomers, and synthesis of thermoplastic and thermosetting polymers from biological sources. Analytical tools and instrumentation, such as titration methods, NMR, FTIR, and GPC, are used to characterize the resulting chemicals and monomers. Polymerization of the monomers and characterization of the polymer properties, including molecular weight, functionality, and thermal and mechanical properties, are integral to the investigation.

**Principal Investigator:** John La Scala      [john.j.lascala.civ@mail.mil](mailto:john.j.lascala.civ@mail.mil)      (410) 306-0687

**Supporting Facility:** Polymer Preparation and Characterization  
Laboratories and MMSD Laboratories (APG)

Laboratories to chemically prepare and characterize monomers and polymers, laboratories to formulate and compound polymers, laboratories to evaluate thermal and mechanical properties of polymers.

**Equipment Available:** Bruker 600 MHz NMR, picospin NMR, fume hoods, GC, Thinky Mixer, Nicolet FTIR, TA Q800 DMAs, DSCs, TGAs, TMAs, AR1000 Rheometer, Hitachi SEM, Instron mechanical testing laboratories.

## Materials Manufacturing & Processing Science

Cryogenic Processing of Nano-Materials. Investigate processing windows suitable for manufacturing to enable production of nano-particles via liquid nitrogen attrition.

**Principal Investigator:** Kyu Cho      [kyu.c.cho2.civ@mail.mil](mailto:kyu.c.cho2.civ@mail.mil)      (410) 306-0820

**Supporting Facility**

Cryogenic Processing Research Facility (APG)

Conduct cryogenic manufacturing and processing of nano-materials.

**Equipment Available:** Cryogenic (liquid nitrogen) Attritor, Glove Box evaporator, power degassing unit.

## Materials State Awareness for Aviation Sustainment

Develop embedding sensing capability for military aircraft composite structures to identify, characterize, and categorize specific materials damage precursors that can be used to predict failure of aircraft structures prior to the onset of actual damages. Explore and establish full understanding of science and technology to detect and

identify material damage precursors prior to the onset of any material damages/flaws in composite materials systems.

Principal Investigator: Asha Hall [asha.j.hall.civ@mail.mil](mailto:asha.j.hall.civ@mail.mil) (410) 278-8036

## Multiscale Reactive Modeling for Energetics

Theoretical Modeling and Simulations of Energetic Materials in order to understand the structure-property and structure-phenomenological responses of Energetics. The program focuses on building models from Quantum Mechanical to Micro- to Meso- to Continuum scale with emphasis on building the models that bridge the length scales.

Principal Investigator: Betsy Rice [betsy.rice.civ@mail.mil](mailto:betsy.rice.civ@mail.mil) (410) 306-1904

## Phonon Dynamics and Transport in Condensed Matter

This program focuses on femtosecond ultrasonics and thermoreflectance studies of phonon transport across interfaces, elastic properties, and phonon attenuation, as well as pump-probe studies of interaction between electronic and phonon excitations.

Principal Investigator: Michael Wraback [michael.wraback.civ@mail.mil](mailto:michael.wraback.civ@mail.mil) (301) 394-1459

### Supporting Facility: Femtosecond Pump-Probe Laboratory (ALC)

This program focuses on femtosecond ultrasonics and thermoreflectance studies of phonon transport across interfaces, elastic properties, and phonon attenuation, as well as pump-probe studies of interaction between electronic and phonon excitations.

**Equipment Available:** Light source includes femtosecond Coherent RegA pumped-optical parametric amplifier (OPA) tunable from UV through IR wavelengths; femtosecond Spectra-Physics Tsunami pumped-inspire high-repetition rate oscillator system tunable from visible through infrared wavelengths.

## Physics of Quantum Phenomena

Investigate quantum phenomenon in semiconductor-light interactions for applications in quantum information using coherence spectroscopy. Strong collaborations with ARL theorists.

Principal Investigators: Michael Wraback [michael.wraback.civ@mail.mil](mailto:michael.wraback.civ@mail.mil) (301) 394-1459  
 Gregory Garrett [gregory.a.garrett.civ@mail.mil](mailto:gregory.a.garrett.civ@mail.mil) (301) 394-1966  
 Grace Metcalfe [grace.d.metcalfe.civ@mail.mil](mailto:grace.d.metcalfe.civ@mail.mil) (301) 394-2864

**Supporting Facility: Coherent Spectroscopy Laboratory (ALC)**

Four-wave mixing techniques including pump-probe spectroscopy, differential reflection/transmission, and photon echo.

**Equipment Available:** Light source includes femtosecond Spectra-Physics Tsunami pumped-inspire high-repetition rate oscillator system tunable from visible through infrared wavelengths.

**Semiconductor Physics (Vis-NIR through Terahertz)**

Investigate carrier dynamics and transport in semiconductor materials used in optoelectronic devices, such as infrared (IR) detectors, solar cells, and liquid/semiconductor junctions using unique Vis/near-IR through terahertz (THz) ultrafast spectroscopy in combination with modeling and data analysis.

**Principal Investigators:** Michael Wraback      [michael.wraback.civ@mail.mil](mailto:michael.wraback.civ@mail.mil)      (301) 394-1459  
Grace Metcalfe      [grace.d.metcalfe.civ@mail.mil](mailto:grace.d.metcalfe.civ@mail.mil)      (301) 394-2864

**Supporting Facility: Visible, Near-Infrared (IR), and Terahertz (THz) Spectroscopy Laboratories (ALC)**

Time-resolved photoluminescence in ranges including near IR, Medium-Wave Infrared (MWIR) (3-5 microns) and Long-Wave Infrared (LWIR) (8-10 microns), time-resolved THz spectroscopy, pump-probe spectroscopy with tunable pulses between 400 nm and 10000 nm, combined pump-probe and THz spectroscopy, continuous-wave THz spectroscopy with tunability from 0.09 THz to 1.2 THz.

**Equipment Available:** Light source includes femtosecond Coherent RegA pumped-OPA tunable from visible through long-wave infrared wavelengths; custom-built continuous-wave THz spectroscopy facility containing sample cells with path lengths from 0.5 m to 9.5 m, and multiple photomixer/Schottky diode sources and detectors to control spectral resolution and tunable range, including coherent heterodyne detection.

**Structural Materials for Improved Vehicle Mobility and Stealth**

Research multifunctional structural materials capable of storing or harvesting energy in pursuit of increased vehicle range and concealed vehicle location.

**Principal Investigator:** Mark Bundy      [mark.l.bundy2.civ@mail.mil](mailto:mark.l.bundy2.civ@mail.mil)      (410) 278-4318

**Lightweight Structural Energy Storage Materials for Vehicles or Energy Harvesting Materials for Combustion Engine Sound Abatement (APG)**

Investigate the assembly of flexible/moldable Si-Li energy storage designs into the structure of small unmanned vehicles. Investigate phenomenological modeling of magnetostrictive shunt damper configuration to maximize the shunt damper performance for reducing the sound emission of combustion engines. Investigate technologies and materials for reducing the structural vibration and acoustic emission from combustion engine platforms.



**Principal Investigators:**

Mark Bundy [mark.l.bundy2.civ@mail.mil](mailto:mark.l.bundy2.civ@mail.mil) (410) 278-4318  
 Jin Yoo [jin.h.yoo6.civ@mail.mil](mailto:jin.h.yoo6.civ@mail.mil) (410) 278-7758

**Ground Vehicle Structural Mechanics and Dynamics Technology**

Establish and evaluate non-linear control algorithms for active and semi-active dynamic systems. Establish non-linear modeling and simulation capabilities to address ground vehicle crashworthiness and Soldier protection.

**Principal Investigator:** Muthuvel Murugan [muthuvel.murugan.civ@mail.mil](mailto:muthuvel.murugan.civ@mail.mil) (410) 278-7903

Establish a phenomenological model for magnetostrictive material behavior. For instance, obtain a numerical expression for the strain and magnetization response as functions of applied magnetic field and external stress. Use the model to predict the performance of magnetostrictive material in the role of an actuator or a sensor for responding to or monitoring vehicle dynamics.

**Principal Investigator:** Jin Yoo [jin.h.yoo6.civ@mail.mil](mailto:jin.h.yoo6.civ@mail.mil) (410) 278-7758

**Supporting Facility:** Structural Integrity Laboratory (APG)

**Equipment Available:** LS-DYNA software, dSpace hardware, MTS for damper testing.

**Ultrafast Spectroscopy of Electronic, Optoelectronic, & Structural Materials**

Femtosecond spectroscopy with ultrashort pulses tunable from 200 nm to 10000 nm, probing dynamics, and transport of electronic and phonon excitations in condensed matter.

**Principal Investigator:** Michael Wraback [michael.wraback.civ@mail.mil](mailto:michael.wraback.civ@mail.mil) (301) 394-1459

**Supporting Facility:** Ultrafast Spectroscopy Laboratories (ALC)

Multiple laboratories providing femtosecond spectroscopy with lasers continuously tunable from 200 nm to 10000 nm.

**Carrier Localization and Recombination Dynamics in Semiconductor Alloys (ALC)**

Investigate the impact of alloy and interface fluctuations in semiconductor alloys on carrier transport and recombination using femtosecond pump-probe, electroabsorption, and luminescence.

**Principal Investigator:** Michael Wraback [michael.wraback.civ@mail.mil](mailto:michael.wraback.civ@mail.mil) (301) 394-1459

**Radiation and Doping Effects on Minority Carrier Lifetimes in Wide Bandgap Semiconductors (ALC)**

Investigate the impact of radiation dosage and doping on minority carrier lifetime using a time-resolved pump probe and luminescence.

**Principal Investigator:** Michael Wraback [michael.wraback.civ@mail.mil](mailto:michael.wraback.civ@mail.mil) (301) 394-1459

**Measurement of Thermal and Elastic Properties and Phonon Transport in Textured Ceramics and Wide Bandgap Materials (ALC)**

Investigate acoustic phonon propagation in transparent ceramics and other wide bandgap materials as a function of texturing, as well as phonon transport at interfaces of these materials with metals and wide bandgap semiconductors.

**Principal Investigator:** Michael Wraback      [michael.wraback.civ@mail.mil](mailto:michael.wraback.civ@mail.mil)      (301) 394-1459

**Strong Coupling in Nitride Semiconductor Quantum Dots (ALC)**

Investigate the coherent transient properties of nitride semiconductor quantum dots in the strong coupling regime.

**Principal Investigator:** Gregory Garrett      [gregory.a.garrett.civ@mail.mil](mailto:gregory.a.garrett.civ@mail.mil)      (301) 394-1966

**High Field Carrier Dynamics and Transport in Deep UV Photodetectors (ALC)**

Investigate carrier dynamics and transport above the direct bandgap in SiC and Si deep UV photodetectors.

**Principal Investigator:** Michael Wraback      [michael.wraback.civ@mail.mil](mailto:michael.wraback.civ@mail.mil)      (301) 394-1459

**Hot Carrier Assisted Transport Across Liquid/Semiconductor Junctions (ALC)**

Investigate the creation of semiconductor heterostructures that enable electron velocity and energy overshoot at a liquid/semiconductor junction and their impact on transport across the junction.

**Principal Investigator:** Michael Wraback      [michael.wraback.civ@mail.mil](mailto:michael.wraback.civ@mail.mil)      (301) 394-1459

**Nonlinear Optical Properties of III-Nitride Polar and Nonpolar Heterostructures (ALC)**

Employ ultrafast spectroscopy to investigate the optical switching dynamics in III-Nitride polar and nonpolar heterostructures for optical modulators.

**Principal Investigator:** Michael Wraback      [michael.wraback.civ@mail.mil](mailto:michael.wraback.civ@mail.mil)      (301) 394-1459

**Wide Band Gap Semiconductor Physics**

Investigate carrier dynamics and transport in semiconductor materials used in light-emitting devices, such as light-emitting diodes (LEDs) and lasers, and photodetectors and energy conversion devices operating in the ultraviolet (UV) through visible spectral range using unique UV-visible ultrafast spectroscopy facility, in conjunction with modeling and data analysis.

**Principal Investigators:** Michael Wraback      [michael.wraback.civ@mail.mil](mailto:michael.wraback.civ@mail.mil)      (301) 394-1459

Gregory Garrett      [gregory.a.garrett.civ@mail.mil](mailto:gregory.a.garrett.civ@mail.mil)      (301) 394-1966

**Supporting Facility: Ultraviolet (UV)-Visible Spectroscopy Laboratory (ALC)**

UV (200-400 nm)-visible time-resolved photoluminescence including unique sub-picosecond optical gating, time-correlated single photon counting, and synchronous-scan streak camera. Continuous-wave photoluminescence. Femtosecond pump-probe spectroscopy with tunable UV pump and probe pulses.

**Equipment Available:** Light source includes femtosecond Coherent RegA pumped-optical parametric amplifier (OPA) tunable from UV through visible wavelengths, and high brightness, broadband, continuous-wave energetic laser-driven UV light source.

## Electronic Materials, Devices, and Circuits

This program focuses on areas of modeling, processing, fabrication, and metrology of advanced electronic materials & devices to enable more efficient high frequency circuits.

**Principal Investigator:** Romeo D Del Rosario      romeo@arl.army.mil      (301) 394-3562

### Emerging Technologies for Semiconductors (ALC)

Characterization and control of trace impurities, defects and interfaces in semiconductors and masks are of interest, particularly for sub90-nm devices and circuits.

**Principal Investigator:** Glen Birdwell      anthony.g.birdwell.civ@mail.mil      (301) 394-0601

### Emerging Technologies for Semiconductors (ALC)

Principal emphasis is on surface or interface control during processing of these materials, characterization of their near-surface transport behavior and surface properties, and modeling or theoretical predictions of their properties.

**Principal Investigator:** Tony Ivanov      tony.g.ivanov.civ@mail.mil      (301) 394-3568

## III-V Devices

This program focuses on improved microwave and mm-wave (up to 200 GHz) devices that are reliable and cost effective to handle large volumes of data on a real-time basis.

**Principal Investigator:** Romeo D Del Rosario      romeo@arl.army.mil      (301) 394-3562

### III-V Devices (ALC)

Physics-based modeling of microwave devices, components, packages, and radiating structures using semiconductor analysis and computational electromagnetic.

**Principal Investigator:** John Penn      john.e.penn16.civ@mail.mil      (301) 394-3568

### III-V Devices (ALC)

Model extraction techniques to obtain lumped element models for circuit designs up to the GHz to THz frequency range, Devices support RF/power applications for operating in extreme environments such that high temperature performance and thermal management and packaging issues become critical.

**Principal Investigator:** Edward Viveiros      edward.a.viveiros2.civ@mail.mil      (301) 394-0930

## Silicon Analog and Mixed Signal Integrated Circuits

This program focuses on areas of broadband integrated circuit design with leading edge nodes/technologies and analysis to enable efficient (low power) broadband complex-modulated vector-waveforms for applications in communication, radar and electronics warfare.

**Principal Investigator:** Romeo D Del Rosario      romeo@arl.army.mil      (301) 394-3562

**Silicon Analog and Mixed Signal Integrated Circuits (ALC)**

Novel broadband high-frequency circuits and techniques for modulation and demodulation of complex waveforms including circuits and techniques to generate and distribute highly stable and low jitter clock signals.

**Principal Investigator:** James Wilson      james.e.wilson889.civ@mail.mil      (301) 394-0328

## Sciences for Maneuver

The Sciences for Maneuver area is focused on gaining a fundamental understanding of advanced mobility systems and their supporting architectures. This area heavily relies on ARL's research expertise and facilities devoted to decision support sciences, autonomy, and high-efficiency energy generation, storage, and distribution. Discoveries, innovations, and developments made in this area are expected to significantly impact the Army of the future by greatly enhancing mobility. ARL's Sciences for Maneuver research is focused on gaining a greater fundamental understanding of advanced mobility systems and their supporting architectures—critical to the future Army's movement, sustainment, and maneuverability. Knowledge gained through these research efforts will lead to technological developments that make it possible to design, fabricate, integrate, control, and support platforms that will have a significant impact on Power Projection Superiority for the Army of 2030.

ARL's basic and applied research in the Sciences for Maneuver area specifically emphasizes Energy and Propulsion, Platform Mechanics, Platform Intelligence, and Logistics and Sustainability.

**Energy and Propulsion** concentrates on understanding and exploiting the applications of energy generation, storage, conversion, and management. The goal of this research is to provide energy and power applications to enhance Army operational effectiveness, improve efficiency, and accelerate development of critical military platform systems ensuring Army Power Projection superiority.

**Platform Mechanics** focuses on fundamental research that enables the development of the highly maneuverable platforms for the Army of the future. Knowledge gained in this area is expected to impact a wide array of vehicle systems, including the ground, air, and maritime domains, as well as from micro- to macro-scales.

**Platform Intelligence** focuses upon fundamental research that enables effective teaming of Soldiers and robots to conduct maneuver and military missions. ARL's activities are centered upon enhancing the autonomous capabilities of unmanned systems. Knowledge gained in this area is expected to impact a wide array of vehicle systems, including the ground, air, and maritime domains, ranging from micro- to macro-scales.

**Logistics and Sustainability** focuses on fundamental research to enable the rapid and reliable assessment of future Army platform reliability, health, and usage. Knowledge gained in this area is expected to impact a wide array of vehicle systems, including the ground, air, and maritime domains, ranging from micro- to macro-scales.

Active research areas and specific projects seeking Open Campus collaborative engagement include:

### Autonomy and Collaboration

Develop novel techniques that enable the teaming of autonomous systems with Soldiers. These behaviors include autonomous 3D mapping, positioning, and exploration in urban environments; heterogeneous teaming; and semantic scene and activity understanding.

**Principal Investigator:**     Stuart Young                      [stuart.h.young.civ@mail.mil](mailto:stuart.h.young.civ@mail.mil)                      (301) 394-5618

**Autonomous Systems Control (ALC)**

Connect system control algorithms with dynamically constructed environment models to enhance robotic control methods. Investigate the use of hierarchies of robots for multiagent tracking applications.

**Principal Investigator:** Ethan Stump [ethan.a.stump2.civ@mail.mil](mailto:ethan.a.stump2.civ@mail.mil) (301) 394-1222

**Ground Vehicle Structural Mechanics and Dynamics Technology**

Establish and evaluate nonlinear control algorithms for active and semi-active dynamic systems, and establish nonlinear modeling and simulation capabilities to address ground vehicle crashworthiness and Soldier protection.

**Principal Investigator:** Muthuvel Murugan [muthuvel.murugan.civ@mail.mil](mailto:muthuvel.murugan.civ@mail.mil) (410) 278-7903

**Phenomenological Model for Magnetostrictive Material Behavior (APG)**

Establish a numerical expression for the strain response as functions of applied magnetization and external stress, and predict the response.

**Principal Investigator:** Jin Yoo [jin.h.yoo6.civ@mail.mil](mailto:jin.h.yoo6.civ@mail.mil) (410) 278-7758

**Supporting Facility: Structural Integrity Laboratory (APG)**

**Equipment Available:** LS-DYNA software, MADYMO; dSpace software license; suspension test rig; electromagnetic high-speed damper tester; drop tower seat testing setup; HIII Crash dummies; Altair HyperWorks.

**Meta-Cognition, Self-reflection and Proprioception**

Develop novel techniques that enable autonomous systems track performance on assigned tasks, recognize failures and adapt or adjust performance. Develop adaptable robotic behavior algorithms that enable autonomous robots to participate in small human/robot team missions with minimal human oversight utilizing techniques from the fields of statistical learning theory, artificial intelligence, and perception. Two topics of particular interest are Recognizing and understanding team behaviors from visual and other sensory information; and adapting autonomous performance to changing conditions.

**Principal Investigator:** MaryAnne Fields [mary.a.fields22.civ@mail.mil](mailto:mary.a.fields22.civ@mail.mil) (410) 278-6675

**Mechanics of Handheld Aerial Mobility**

Develop technologies and understandings to enable and enhance the performance of man-portable aerial systems. Activities are in the areas of Aeromechanics, Actuation, Flight Dynamics and Controls. Specific interests include the development of flight dynamics and control for handheld aerial mobility. Design and implement controllers for handheld aerial systems. Perform system ID on existing vehicles.

**Principal Investigator:** Christopher Kroninger [christopher.m.kroninger.civ@mail.mil](mailto:christopher.m.kroninger.civ@mail.mil) (410) 278-5690



**Supporting Facility: Wind Tunnel (APG)**

A low speed, closed return wind tunnel. The test section is designed to be highly modular and a traversable rail super-structure allows for mounting experimental hardware around the test section. Currently supported experimental techniques include PIV, hot-wire anemometry, static pressure measurement, force and moment measurement.

**Supporting Facility: Oil Tank (APG)**

This is a low Reynolds number (<2500) facility designed for the aerodynamics scaling of insect wings. Currently, six component force measurements can be measured from arbitrarily prescribed 2 DoF wing kinematics.

**Mobility and Manipulation for Next-Generation Unmanned Systems**

Development of theory, controls, and mechanisms (morphology, actuation, propulsion, etc) to provide unmanned systems the physical capabilities required to efficiently navigate and perform work in dynamic 3D environments as an integral part of missions in which they are teamed with Soldiers. Theoretical and experimental studies, including extensive use of modeling and simulation tools for development of algorithmic and computational capabilities to describe the kinematics and dynamics of rigid and deformable multi-body systems and their interaction with the environment with emphasis on advanced robotic systems and biological systems which exhibit unique (ambulation, brachiation, jumping), airborne, and wheeled mobility and dexterous manipulation of their bodies, limbs, and objects within the environment.

**Principal Investigator:** Harris Edge [harris.l.edge.civ@mail.mil](mailto:harris.l.edge.civ@mail.mil) (410) 278-4317

**Semantic Spatial Understanding**

Develop novel techniques that enable autonomous systems to describe objects and their relationships in human understandable terms.

**Principal Investigator:** MaryAnne Fields [mary.a.fields22.civ@mail.mil](mailto:mary.a.fields22.civ@mail.mil) (410) 278-6675

**Multifunctional Vehicle Structures**

The future force will rely on small highly mobile unmanned vehicles to provide perimeter intelligence, surveillance and reconnaissance for small soldier units deployed in hostile unfamiliar environments. There will also be a need for highly mobile manned vehicles to deploy soldier teams to harsh, isolated, remote rural locations. Research on multifunctional vehicle structures will improve the payload capacity, mobility, and operational readiness of future Army vehicles by adding new functionality or consolidating existing single-purpose functionality into multi-role vehicle structures. Currently, material multifunctionality encompasses structural materials that can provide one or more of the following functions: structural health monitoring, energy harvesting or storage, actuation/morphing, signature reduction/concealment.

**Principal Investigators:** Mark Bundy [mark.l.bundy2.civ@mail.mil](mailto:mark.l.bundy2.civ@mail.mil) (410) 278-4318  
 Asha Hall [asha.j.hall.civ@mail.mil](mailto:asha.j.hall.civ@mail.mil) (410) 278-8036  
 Jin Yoo [jin.h.yoo6.civ@mail.mil](mailto:jin.h.yoo6.civ@mail.mil) (410)278-7758

**Supporting Facility/Equipment:** Materials Processing Laboratory (APG) .

**Equipment Available:** Fume hood, glove box, probe sonicator, spin coater, ball mill, balance, vacuum oven, Keithley 4200 semiconductor characterization and Cascade Microtech probe station, Arbin supercap and battery analyzer, Quantum Design Versalab vibrating sample magnetometer, Newport Solar Simulator, JAZ UV-Vis Spectrometer, Instron 5965 tensile tester, Deben Microtensile Stage, electrospinning system.

## Prognostics and Diagnostics for Future Vertical Lift

Establish methodologies to provide warning of impending failure and determine the remaining useful life of structural and dynamic components for Army Future Vertical Lift (FVL) and explore concepts for potentially self-responsive engineered composite materials/structures that employ probabilistic methods. Furthermore, investigate sensor optimization and reduction methods for prognostic health monitoring capability using spatially sparse sensors, by employing the theory of compressive sensing and principles from continuum mechanics to deploy a suboptimal number of sensors without compromising the fidelity of diagnostic measurements. Finally, establish new methods to enable damage precursor mapping leading to total material state awareness, and multi-scale life estimation models to support the "zero-maintenance" vision for Army aviation sustainment.

**Principal Investigators:** Mulugeta Haile [mulugeta.a.haile.civ@mail.mil](mailto:mulugeta.a.haile.civ@mail.mil) (410) 278-5289  
 Jaret Riddick [jaret.c.riddick.civ@mail.mil](mailto:jaret.c.riddick.civ@mail.mil) (410) 278-9831

**Supporting Facility:** Prognostics and Diagnostics Laboratory (APG)

**Equipment Available:** Acoustic Emissions, Optical Fiber Bragg interrogator, Eddy Current Flaw detector, Ultrasonic Flaw detector, Digital Image Correlation, Pulsed Thermography, Acoustic (ToF) flaw detector with SMART sensors and actuators, 22-kip servo-hydraulic Mechanical testing Machine, High speed oscilloscope, LabView data acquisition systems.

## Mechanical Diagnostics and Failure Progression in Aerospace Power Transmission (APG)

Conduct research in innovative fault detection methodologies for aerospace power transfer including gears, bearings, and transmissions. Diagnostic techniques for health monitoring will be developed by seeding artificial faults into experimental articles, and various methods will be employed to establish a robust system of instrumentation and signal processing algorithms for fault detection.

**Principal Investigator:** Adrian Hood [adrian.a.hood.civ@mail.mil](mailto:adrian.a.hood.civ@mail.mil) (410) 278-9581

## Disruptive Technologies for Advanced Power Transmission in Rotorcraft (APG)

The student will participate in the experimental study of helicopter drive system mechanical components including gears, bearings, and transmissions as well as non-mechanical power transmission. Research will focus on improving power density, durability, maintenance costs, and survivability of drive systems in Army helicopters

**Principal Investigator:** Brian Dykas [brian.d.dykas.civ@mail.mil](mailto:brian.d.dykas.civ@mail.mil) (410) 278-9545

#### **High-Efficiency Gas Turbine Engine Components (APG and Army NASA Glenn Research Center Field Element)**

The primary focus of the researcher would be to conduct experimental and computational investigations supporting innovative new technologies enabling next generation propulsion systems for Army air platforms. Possible areas of study include extending the current state-of-the-art in compressors, combustors and turbines. Research may also include evaluation of hybrid systems, adaptive engine/power system architectures, and novel architectures/cycles. The researcher will conduct bench and component-level studies focused on technologies that will seek to optimize future Army Vertical Lift mission performance (fuel consumption, range, time on station, etc.) across the full spectrum of ambient conditions (high hot, high cold, etc.)

#### **Principal Investigators:**

Waldo A. Acosta	<a href="mailto:waldo.a.acosta.civ@mail.mil">waldo.a.acosta.civ@mail.mil</a>	(216) 433-3393
Gary J. Skoch	<a href="mailto:gary.j.skoch.civ@mail.mil">gary.j.skoch.civ@mail.mil</a>	(216) 433-3396
Douglas R. Thurman	<a href="mailto:douglas.r.thurman.civ@mail.mil">douglas.r.thurman.civ@mail.mil</a>	(216) 433-6573
Anindya Ghoshal	<a href="mailto:Anindya.ghoshal.civ@mail.mil">Anindya.ghoshal.civ@mail.mil</a>	(410) 278-7358

#### **Tribological Studies of Rotorcraft Transmission Components for Improved Survivability under Loss-of-Oil Conditions (APG)**

Experimental and computational studies will be conducted on helicopter and ground vehicle drive system components including gears, bearings, and transmissions. Coupon-level fundamental studies will focus on physical failure mechanisms for helicopter transmissions under loss-of-oil conditions, with a focus on improving vehicle survivability.

**Principal Investigator:** Brian Dykas [brian.d.dykas.civ@mail.mil](mailto:brian.d.dykas.civ@mail.mil) (410) 278-9545

#### **Tribology and Lubrication Science for High Performance Power Transmission (APG)**

Innovative approaches are needed to create material and tribological solutions for high performance and extreme lubrication conditions. These approaches may consist of engineered surface structures, thin solid films, functional coatings, modified surface chemistry, nanoscale or colloidal lubricant additives, and novel lubricant chemistry.

**Principal Investigators:** Brian Dykas [brian.d.dykas.civ@mail.mil](mailto:brian.d.dykas.civ@mail.mil) (410) 278-9545  
 Adrian Hood [Adrian.a.hood.civ@mail.mil](mailto:Adrian.a.hood.civ@mail.mil) (410) 278-9581

#### **Aerospace Power Transmission Component Research (APG and Army NASA Glenn Research Center Field Element)**

Conduct experimental and computational investigations supporting innovative new technologies enabling next generation power transmission for military propulsion. Possible areas of study include extending the current state-of-the-art in alternative bearing concepts for both low speed and high speed applications. Research may include evaluation of potential coatings, hybrid material systems, surface modifications, and new materials for use in geared systems.

**Principal Investigators:** Kelsen LaBerge [Kelsen.E.LaBerge.civ@mail.mil](mailto:Kelsen.E.LaBerge.civ@mail.mil) (216) 433-2078  
 Adrian Hood [Adrian.a.hood.civ@mail.mil](mailto:Adrian.a.hood.civ@mail.mil) (410) 278-9581

### Technology Improvement Studies of Rotorcraft Transmission Components for Improved Efficiency, Durability, Vibration, or Acoustic Performance (APG and Army NASA Glenn Research Center Field Element)

Experimental and computational studies will be conducted on helicopter and ground vehicle drive system components including gears, bearings, and transmissions. systems, surface modifications, and new materials for use in geared systems. Methodologies for characterizing ultra high-cycle fatigue failure mechanisms and control technologies for efficiently performing these experiments are of interest.

**Principal Investigators:** Kelsen LaBerge [Kelsen.E.LaBerge.civ@mail.mil](mailto:Kelsen.E.LaBerge.civ@mail.mil) (216) 433-2078  
Adrian Hood [Adrian.a.hood.civ@mail.mil](mailto:Adrian.a.hood.civ@mail.mil) (410) 278-9581

### Extremely Lightweight, Adaptive, Durable, Damage Tolerant Structures for Future Vertical Lift

Investigate novel concepts for extremely lightweight, adaptive, durable, damage tolerant (XLADD) structures enabled by advanced materials and designs for Army Future Vertical Lift (FVL). Apply novel nonlinear computational methods and new physics-based models to notional structural concepts to simulate the response of metallic and composite structures, as well as failure initiation and propagation to produce robust validated modeling capability. On-going research encompasses a wide range of basic research to address XLADD including the following topics: durable, high strength composite/metallic and multifunctional damage tolerant (MFDT) structural configurations and designs; non-linear and physics-based computational methods; advanced probabilistic algorithms for fatigue life management with increased prediction accuracy and reduced computational time; and additive manufacturing of multifunctional fatigue-resistance lightweight components.

**Principal Investigators:** Jaret Riddick [jaret.c.riddick.civ@mail.mil](mailto:jaret.c.riddick.civ@mail.mil) (410) 278-9831  
Robert Haynes [robert.a.haynes43.civ@mail.mil](mailto:robert.a.haynes43.civ@mail.mil) (410) 278-8035

**Supporting Facility:** Structural Integrity and Durability Laboratory (APG)

**Equipment Available:** 22-kip servo-hydraulic Mechanical Testing Machines with assortment of ASTM standard test Fixtures, 1-kHz, 5-kip "High Cycle Fatigue" servo-hydraulic Mechanical Testing Machine, 5 kN Electromechanical testing machine with environmental chamber, Digital Image Correlation, Stratasys Dimension Elite Performance 3D Printer.

### Spray and Combustion Science for Advanced Combustion Systems (APG)

Research various fuel injectors and fuels in high-temperature and high-pressure conditions to advance spray and combustion models which will be embedded in commercial engine codes to facilitate advanced engine development; develop advanced optical diagnostic methods.

**Principal Investigator:** Chol-Bum "Mike" Kweon [chol-bum.m.kweon2.civ@mail.mil](mailto:chol-bum.m.kweon2.civ@mail.mil) (410) 278-9319

**Investigation on the Spray and Combustion Processes of Various Military Fuels using Optical Diagnostics (APG)**

Investigate the detailed spray and combustion processes of various fuel injector designs and fuel properties (diesel, JP-8, Jet A, alternative JP-8, ATJ fuels) to further the fundamental understanding of the fuel physical and chemical effects on engine combustion.

**Principal Investigators:**

Chol-Bum "Mike" Kweon	<a href="mailto:chol-bum.m.kweon2.civ@mail.mil">chol-bum.m.kweon2.civ@mail.mil</a>	(410) 278-9319
Matthew Kurman	<a href="mailto:matthew.s.kurman.civ@mail.mil">matthew.s.kurman.civ@mail.mil</a>	(410) 278-8971

**Supporting Facility: Spray Combustion Research Laboratory (APG)**

ARL has an operating high-temperature pressure vessel (HTPV) system with various laser diagnostics to measure liquid spray and combustion processes, three (3) different fuel benches (one common-rail fuel bench, one hydraulically-actuated electronically-controlled unit injector fuel bench, and one air pump-driven fuel bench) to deliver fuels to an injector at various fuel pressures (over 2000 bars with the air pump-driven fuel bench) with different injector types, an injector analyzer bench to characterize and map an injector, and various injector samples. The HTPV has the capability of up to 150 bar chamber pressure, 1000 K chamber temperature, and 0 to 21% oxygen concentrations in the test section. All three parameters can be independently controlled. This laboratory is established to (1) provide the understanding of the injector performance under 'realistic' operating conditions for various injector parameters, (2) provide the understanding of the impact of fuel properties on the detailed spray and combustion processes, (3) to generate the database of spray and combustion measurements. These data are being used in 3D CFD to simulate real engine spray and combustion processes that include piston motion and in-cylinder turbulence.

**Equipment Available:** High-temperature pressure vessel system, high-speed Mie and Schlieren imaging, shadowgraph imaging, planar laser-induced fluorescence (PLIF), laser-induced fluorescence (LIF), laser-induced incandescence (LII), Raman spectrograph, Raleigh thermometry, high-speed CMOS camera, CCD camera, and various other optics, LaVision Davis packages, IAV injection analyzer, common-rail fuel bench, HEUI fuel bench, and air-driven pump fuel bench.

## Information Sciences

The Information Sciences area is focused on gaining a fundamental understanding of information generation, collection, assurance, distribution, and exploitation; high-performance electronic components and devices; and synthetic biological systems. This area heavily relies on ARL's research expertise and facilities in network science; decision support sciences; electronic & information warfare vulnerability; electronic materials synthesis, component fabrication, and device characterization; and manipulation of synthetic biological systems. Discoveries and innovations made in this area are expected to exert a significant impact on the Army embodied as improved sensing capabilities, improved tactical networks, improved commander's decision support aids, and robust computational resources leading to information supremacy.

Information Sciences research emphasis areas include Battlefield Information Sensing and Effecting, System Intelligence and Intelligent Systems, Human and Information Interaction, Networks and Communications, and Cyber Security research. These areas collectively comprise ARL's Information Sciences research campaign, which heavily relies on ARL's research expertise and facilities in network science; human cognitive and decision support sciences; physical and software intelligent systems; electronic & information warfare vulnerability; electronic materials synthesis, component fabrication, and device characterization; sensing and modeling of complex battlefield environments; high-performance computing; and cyber defense and forensics. Discoveries and innovations made in this area are expected to exert a significant impact on the Army embodied as improved sensing capabilities, enhanced tactical networks, effective decision support aids, intelligent systems that team with Soldiers, and robust computational capabilities leading to information supremacy.

**Sensing and Effecting** research concentrates on understanding and exploiting information gained through sensing exploiting data to drive effectors. Both sensing and effecting necessitate detailed understanding of corresponding physical behaviors that generate and utilize data, as well as effective means for storage, retrieval, and manipulation of data.

**System Intelligence and Intelligent Systems** research concentrates on understanding and exploiting interactions between information and intelligent systems, such as robots and software agents, wherein information is transformed between different levels of abstraction and roles within the intelligent system's cognitive processes—recognition, reasoning, predictions, and decision-making.

**Human and Information Interaction** research concentrates on understanding and exploiting interactions between information and humans, which involves complex mixed-initiative processes of information acquisition, transformation between levels of abstraction and relevance, comprehension, negotiation and interactive tasking, mutually between humans and Army information systems.

**Networks and Communications** research concentrates on understanding and exploiting information's interactions with socio-technical networks, particularly communications, and command & control networks, both formal and social. Such interactions are heavily influenced by complex channels and protocols requiring complex analyses to understand and predict emergent behaviors of networks.

**Cyber Security** research concentrates on understanding and exploiting interactions of information with cyber attackers—human and/or intelligent agents. These interactions involve friendly operations against adversary information



systems and networks, defense of friendly information systems and networks, and assurance of persistent information support to Soldiers even when parts of the friendly systems and networks are compromised.

Active research areas and specific projects seeking Open Campus collaborative engagement include:

### Bio-Aerosols Isolation and Characterization

Individual bio-aerosol particles are isolated and trapped using laser-induced photophoretic forces. Methods are under development to fully determine fluorescence, Raman and thermal emission, and elastic scattering from the trapped particles, extracting detailed characteristics of the aerosols from relatively limited measurements. Methodologies are developed to precisely identify/characterize hazardous bio-aerosols.

**Principal Investigator:**     Chatt Williamson     [chatt.c.williamson.civ@mail.mil](mailto:chatt.c.williamson.civ@mail.mil)     (301) 394-1771

### Supporting Facility: Aerosol Research Facility (ARF) (ALC)

This facility is used to develop methods for the detection, trapping, and characterization of atmospheric aerosols, dust, haze, and other battlefield obscurants. The ARF provides physical, chemical, and biological characterization; optical cross sections; and spectral signatures of the aerosols.

**Equipment Available:** polarimetric imager, nephelometers, specially tuned laser.

### Cloudlet-Based Processing

Develop optimization approaches to allow for self-forming "cloudlet"-based processing configurations with HPC assets providing key processing and offloading support for constrained hand-held devices. Develop models to account for network connectivity and offered computing load as mapped to a dynamic computing infrastructure (computing capacity). Develop new methodologies or apply existing concepts related to scheduling to achieve balance in transient and unstable networks common in Army operational realms.

**Principal Investigator:**     David Bruno     [david.l.bruno4.civ@mail.mil](mailto:david.l.bruno4.civ@mail.mil)     (410) 278-8929

### Verification and Validation of Cloudlet Provisioning Using EMANE (APG)

The Extendable Mobile Ad-hoc Network Emulator (EMANE) is a useful system to verify and validate network-based protocols. This project will investigate how to extend the system for models under development at ARL and also test current models being proposed for non-ad-hoc networks for scalability and performance.

**Principal Investigator:**     David Doria     [david.l.doria.civ@mail.mil](mailto:david.l.doria.civ@mail.mil)     (410) 278-2310

### Scheduling and Provisioning within Army Cloudlets (APG)

This research involves investigating new model developments to couple mobile ad hoc networking with computing assets deployed in the field. Approximation methods will be investigated to facilitate provisioning and scheduling in real time.

**Principal Investigator:**     David Bruno     [david.l.bruno4.civ@mail.mil](mailto:david.l.bruno4.civ@mail.mil)     (410) 278-8929

## Domain-Specific Languages

Perform research into the utility of domain-specific languages to achieve high efficiency on advanced computing architectures to promote portability and longevity while reducing the burdens on computational scientists to develop software. Develop quantitative and qualitative assessment methodologies to assess performance.

**Principal Investigator:** David Bruno      [david.l.bruno4.civ@mail.mil](mailto:david.l.bruno4.civ@mail.mil)      (410) 278-8929

### Investigation of Terra-Lua Approach for DSLs (APG)

ARL and Stanford University are working on the creation of DSLs targeting, in this case, finite element codes. This project will perform analysis of the Terra-Lua approach as it maps to a large-scale hybrid computing system using standard cores and GPU-based technologies.

**Principal Investigator:** Dale Shires      [dale.r.shires.civ@mail.mil](mailto:dale.r.shires.civ@mail.mil)      (410) 278-5006

## Natural Language Processing (NLP)

This effort will focus on adaptive machine translation (MT) research using predictive modeling techniques that leverage lexical, syntactic, and semantic natural language processing (NLP) resources against large-scale, heterogeneous document collections.

**Principal Investigator:** Melissa Holland      [virginia.m.holland6.civ@mail.mil](mailto:virginia.m.holland6.civ@mail.mil)      (301) 394-3001

### Bot-Language (ALC)

Using formal logic specifications built from natural language mission descriptions, generate reactive controllers that govern low-level robot behaviors. Explore the application of these specifications to enhance Soldier-machine interfaces.

**Principal Investigator:** Melissa Holland      [virginia.m.holland6.civ@mail.mil](mailto:virginia.m.holland6.civ@mail.mil)      (301) 394-3001

### NLP for Cultural Understanding (ALC)

Automation of the processing, analysis, and interpretation of text, including very low-resource foreign languages and social media, to support social network construction and relationship discovery from text toward new dimensions of socio-cultural insight.

**Principal Investigator:** Melissa Holland      [virginia.m.holland6.civ@mail.mil](mailto:virginia.m.holland6.civ@mail.mil)      (301) 394-3001

## Network Science

Apply non-equilibrium statistical physics to complex networks.

**Principal Investigator:** Bruce J. West      [bruce.j.west.civ@mail.mil](mailto:bruce.j.west.civ@mail.mil)      (919) 549-4257

## Network & Information Sciences: Quality of Information

Development of foundational framework, including ties with semantic information theory, and propagation of information in composite dynamic networks.

**Principal Investigators:** Ananthram Swami [ananthram.swami.civ@mail.mil](mailto:ananthram.swami.civ@mail.mil) (301) 394-2486  
 Greg Cirincione [gregory.h.cirincione.civ@mail.mil](mailto:gregory.h.cirincione.civ@mail.mil) (301) 394-4809

**Supporting Facility:** Mobile Network Modeling Institute (APG)  
 Facility for fine-grained simulation and emulation of communication networks.

## Network & Information Sciences: Co-evolution of Networks

Development of empirical and theoretical models; tools for discovery, inference, prediction and control; and experimental validation.

**Principal Investigators:** Ananthram Swami [ananthram.swami.civ@mail.mil](mailto:ananthram.swami.civ@mail.mil) (301) 394-2486  
 Bruce J. West [bruce.j.west.civ@mail.mil](mailto:bruce.j.west.civ@mail.mil) (919) 549-4257

### Quality of Information (ALC)

Develop a foundational framework, including ties with semantic information theory; develop models for propagation of information in composite dynamic networks; and experimental validation.

**Principal Investigators:** Ananthram Swami [ananthram.swami.civ@mail.mil](mailto:ananthram.swami.civ@mail.mil) (301) 394-2486  
 Greg Cirincione [gregory.h.cirincione.civ@mail.mil](mailto:gregory.h.cirincione.civ@mail.mil) (301) 394-4809

### Group Structures in Composite Networks (ALC)

Empirical study of group structures in multiple collaboration and other social networks and development of models of evolution.

**Principal Investigators:** Ananthram Swami [ananthram.swami.civ@mail.mil](mailto:ananthram.swami.civ@mail.mil) (301) 394-2486  
 Terrence Moore [terrence.j.moore.civ@mail.mil](mailto:terrence.j.moore.civ@mail.mil) (301) 394-1236

### Network Science (ALC)

Develop theories and experimentally validated models for the structure, dynamics, and interactions of co-evolving networks; develop metrics for composite dynamic networks; determine how processes and parameters in one network affect and are affected by those in the co-evolving networks; predict and control individual and composite behavior of these complex interacting networks.

**Principal Investigator:** Hasan Cam [hasan.cam.civ@mail.mil](mailto:hasan.cam.civ@mail.mil) (301) 394-2871

### Network Tomography (ALC)

Development of theories, fundamental performance bounds, algorithms, and performance guarantees for inference of network state and topology from partial and inaccurate information in dynamic and stochastic settings; and detection of changes.

**Principal Investigator:** Ananthram Swami [ananthram.swami.civ@mail.mil](mailto:ananthram.swami.civ@mail.mil) (301) 394-2486

### Co-Evolution & Dynamics of Networks (ALC)

Develop framework for modeling co-evolution and dynamics in inter-genre networks, including large and adversarial network. Characterize co-evolution of structural vs. functional/behavioral traits. Develop tools for discovery, inference, and prediction in inter-genre networks.

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**Principal Investigators:** Ananthram Swami [ananthram.swami.civ@mail.mil](mailto:ananthram.swami.civ@mail.mil) (301) 394-2486  
Terry Moore [terrence.j.moore.civ@mail.mil](mailto:terrence.j.moore.civ@mail.mil) (301) 394-1236

### Models of Information Propagation in Composite Networks (ALC)

Model social influence using probabilistic graph models; exploit tensor decomposition to transform graphical models into structurally simpler graphical models; and develop inference and prediction techniques (for both static and dynamic networks).

**Principal Investigator:** Ananthram Swami [ananthram.swami.civ@mail.mil](mailto:ananthram.swami.civ@mail.mil) (301) 394-2486

### Quality of Information (ALC)

Development of foundational framework, including ties with semantic information theory; development of an appropriate theory of information. Extensions of subjective logic for fusion for QoI.

**Principal Investigators:**

Ananthram Swami	<a href="mailto:ananthram.swami.civ@mail.mil">ananthram.swami.civ@mail.mil</a>	(301) 394-2486
Greg Cirincione	<a href="mailto:gregory.h.cirincione.civ@mail.mil">gregory.h.cirincione.civ@mail.mil</a>	(301) 394-4809
Lance Kaplan	<a href="mailto:lance.m.kaplan.civ@mail.mil">lance.m.kaplan.civ@mail.mil</a>	(301) 394-0807

### Supporting Facility: Network Science Research Laboratory (ALC)

Integrated framework for experimentation on networks.

## Quantum Information Science

Investigate advanced tactical and long-range atmospheric laser communication and imaging technologies to achieve high-bandwidth communication and high-fidelity visualization. Investigate and develop novel processing techniques to provide tactically superior quantum imaging and battlefield communications particularly in obscured, obstructed, or adverse tactical environments. Research topics include experimental and theoretical research in quantum entanglement, quantum imaging, quantum multiphoton interference, quantum information processing, and quantum communications.

**Principal Investigator:** Ronald Meyers [ronald.e.meyers6.civ@mail.mil](mailto:ronald.e.meyers6.civ@mail.mil) (301) 394-2111

## Sensor Fusion and Biometrics

This effort will focus on developing new mathematical tools for multimodal fusion of homogenous/heterogeneous sensor data for display as well as identification, and providing algorithms to identify individuals from their biometrics data.

**Principal Investigator:** Nasser Nasrabadi [nasser.m.nasrabadi.civ@mail.mil](mailto:nasser.m.nasrabadi.civ@mail.mil) (301) 394-0806

## Video and Imaging Understanding

This effort will focus on developing machine learning algorithms in analyzing and labeling image and videos for detection and identification of faces and people's activities. Research in computer vision, machine learning, and statistical techniques for developing new methods for object classification and identification. Emphasis on developing new methods to analyze full motion video for tracking individuals or a group of people. Machine learning techniques will be investigated to recognize people's activities in an unconstrained environment.

**Principal Investigator:** Nasser Nasrabadi [nasser.m.nasrabadi.civ@mail.mil](mailto:nasser.m.nasrabadi.civ@mail.mil) (301) 394-0806

## Sciences for Lethality & Protection

The Sciences for Lethality and Protection area is focused on gaining a fundamental understanding of armor, under body, scalable effects, electronic warfare, and human injury mechanisms. This area heavily relies on ARL's research expertise and facilities in terminal effects; impact physics; weapons physics, guidance and aerodynamics; and ballistic vulnerability. Knowledge gained through these research efforts will lead to technological developments in a broad array of lethality systems as well as resilient and robust vehicle protection systems.

Research emphasis areas include Lethality Research for Soldiers and Army Platforms, Protection Research for Soldiers and Army Platforms, and Battlefield Injury Biomechanics.

**Lethality Research for Soldiers and Army Platforms** concentrates on understanding and exploiting the fundamental aspects of launch and control, electronic attack, directed energy mechanisms, and target effects.

**Protection Research for Soldiers and Army Platforms** concentrates on understanding and exploiting the fundamental aspects of protection against ballistic threats, directed energy threats, and CBRNE threats.

**Battlefield Injury Mechanisms** concentrates on understanding and exploiting the fundamental aspects of human combat injury mechanisms.

Key challenges required to enable disruptive advances in this area include:

- Understanding the interaction of extreme fields with matter.
- Understanding the controlling mechanisms of human ballistic injury and performance.
- Understanding the relationship between aerodynamics and algorithms for navigation and environment constraints including measurement/processing/flight time/GPS denied.
- Understanding robust, reliable, and recoverable nonlethal mechanisms to shut down or dissuade humans.
- Understanding the coupling of physical phenomena—mechanical, electromagnetic, and biological—across the range of military interest.

- Understanding and discovery of very high-energy storage mechanisms and controlled release on desired timescales.
- Understanding the fundamental aspects of frequency agile, high-energy, and short pulse laser interaction with organic, biological, and inorganic materials.

Active research areas and specific projects seeking Open Campus collaborative engagement include:

### Dynamic Failure of Materials

Discover the underlying mechanisms associated with material fracture and failure that occur at very high loading rates, create engineering-level models of the underlying mechanisms, and structure the models in a manner consistent for implementation into advanced computational mechanics codes.

**Principal Investigator:** Todd Bjerke      [todd.w.bjerke2.civ@mail.mil](mailto:todd.w.bjerke2.civ@mail.mil)      (410) 278-5819

#### Supporting Facility: Dynamic Fracture Laboratory (APG)

High-rate loading device and state-of-the-art instrumentation to isolate and probe individual fracture/failure mechanisms.

**Equipment Available:** Gas gun, coherent gradient sensing device, high-powered laser, method of caustics, ultrafast 64 channel IR detector array for measuring thermal emissions furing propagating cracks, strain gages, Hadland cameras.

### Modeling of Dynamic Fracture (APG)

Discover the underlying mechanisms associated with material fracture and failure that occur at very high loading rates, create engineering-level models of the underlying mechanisms, and structure the models in a manner consistent for implementation into advanced computational mechanics codes.

**Principal Investigator:** Todd Bjerke      [todd.w.bjerke2.civ@mail.mil](mailto:todd.w.bjerke2.civ@mail.mil)      (410) 278-5819

### Flight Dynamics/Guidance, Navigation, and Control

Flight dynamics and guidance, navigation, and control of guided precision munitions with emphasis on development of new algorithms of novel guided munitions.

**Principal Investigator:** Frank Fresconi      [frank.e.fresconi.civ@mail.mil](mailto:frank.e.fresconi.civ@mail.mil)      (410) 306-0794

### High-G Environment

Understanding and simulating a structural response to a high-acceleration environment are critical to the effective design of gun-launched projectiles. Development of detailed models of high-g simulation that can be used to tailor test environment.



**Principal Investigator:** Morris Berman [morris.berman@us.army.mil](mailto:morris.berman@us.army.mil) (301) 394-4188

**Interior Ballistic Structural Models (APG)**

Use high-fidelity FE modeling methods to simulate structural response to the interior ballistic environment.

**Principal Investigator:** William Drysdale [william.h.drysdale.civ@mail.mil](mailto:william.h.drysdale.civ@mail.mil) (410) 306-0945

**Supporting Facility:** High-G Environment Simulation Facility (ALC)

Laboratory creation of millisecond-duration high-g environments.

**Equipment Available:** 3" Airgun, 4" Airgun, 7" Airgun.

## High-Rate Experimental Mechanics of Materials at Different Length Scales and Loading Rates

Exploring and understanding the relationship between mechanical, electrical, and chemical response of materials to mechanical loading by identifying associated micro-mechanisms through quantitative in-situ visualization. Investigations are designed to unravel the deformation, failure and injury mechanisms at loading rates and length scales with focus on Army-relevant materials including bio and bio-mimetic materials.

**Principal Investigator:** Tusit Weerasooriya [tusit.weerasooriya@us.army.mil](mailto:tusit.weerasooriya@us.army.mil) (410) 306-0969

**Deformation and Failure Mechanisms for Army-Relevant Materials (APG)**

Understanding the relationship between mechanical, electrical, and chemical response of materials at different length scales to mechanical loading with focus on rates experienced by Soldiers on the battlefield. Developing in situ experimental methods and conducting investigations to identify associated micro-mechanisms through quantitative visualization.

**Principal Investigator:** Tusit Weerasooriya [tusit.weerasooriya@us.army.mil](mailto:tusit.weerasooriya@us.army.mil) (410) 306-0969

## Supporting Facility: Multi-Scale and Multi-Rate Experimental Mechanics Laboratory (APG)

The laboratory has developed many unique in-situ experimental methods at different length-scales to explore the rate-dependent response of materials (including bio materials) using novel loading methods at different rates. Response measuring diagnostics include wide-field, fluorescent, confocal, electron microscopy, macro/micro-DIC methods and micro-CT methods. This lab is in the process of developing in situ X-ray diffraction microscopy (SAXS and WAXS) methods. Mechanical loading devices include specially designed Hopkinson bars and other specialized loading devices to apply Army relevant loading to materials scaling from centimeters to sub-micrometers.

## Humans in Extreme Environments

Understanding the mechanisms of human response to high rate ballistic loading. Develop experimental methods and computational techniques to understand the human response to ballistic loading. Current

research focuses include understanding the response of the brain and the body to ballistic loading conditions including accelerative loading conditions. Experimental investigations in the response of the brain are designed to elucidate neuronal responses from mechanical loading at different rates. Computational techniques are required to accurately represent the rate-dependent response of tissue to applied loading.

**Principal Investigators:** Christopher Hoppel [christopher.p.hoppel.civ@mail.mil](mailto:christopher.p.hoppel.civ@mail.mil) (410) 278-8878  
Tusit Weerasooriya [tusit.weerasooriya@us.army.mil](mailto:tusit.weerasooriya@us.army.mil) (410) 306-0969

#### Supporting Facility: Multi-Scale and Multi-Rate Experimental Mechanics Laboratory (APG)

The laboratory has developed numerous unique in situ experimental methods at different length-scales to explore the rate-dependent response of materials (including bio materials) using novel loading methods at different rates. Response measurement diagnostics include wide-field, fluorescent, confocal, electron microscopy, macro/micro-DIC methods and micro-CT methods. We are also in the process of developing in situ X-ray diffraction microscopy (SAXS and WAXS) methods. Mechanical loading devices include specially designed Hopkinson bars and other specialized loading devices to apply Army relevant loading to materials scaling from centimeters to sub-micrometers.

#### Understanding the Mechanisms of Traumatic Brain Injury (APG)

Develop in situ experimental methods to characterize the neuronal response to different rates of loading including ballistic loading. Develop computational techniques to represent the electrical, mechanical, and chemical responses of the brain to stress waves applied to the body.

##### Principal Investigators:

Christopher Hoppel [christopher.p.hoppel.civ@mail.mil](mailto:christopher.p.hoppel.civ@mail.mil) (410) 278-8878  
Tusit Weerasooriya [tusit.weerasooriya@us.army.mil](mailto:tusit.weerasooriya@us.army.mil) (410) 306-0969

#### Diagnostic Development for Ballistic Experiments

Develop diagnostics capable of measuring material response during ballistic impact events.

**Principal Investigator:** John Runyeon [john.w.runyeon.civ@mail.mil](mailto:john.w.runyeon.civ@mail.mil) (410) 278-6568

#### Diagnostic Development for Ballistic Experiments (APG)

Enhance diagnostic techniques for use in ballistic experiments. The intent is to implement these diagnostic techniques at large scale experimental facilities capable of handling up to 20 lb of high explosive. The goal of this focus area is to increase both the quantity and fidelity of data typically captured during ballistic experiments as well as explore entirely new diagnostic methods. Examples of potential collaborative efforts include development of a) multi-color flash x-ray tomography and b) modern cineradiography capability.

**Investigator:** Michael Zellner [michael.b.zellner.civ@mail.mil](mailto:michael.b.zellner.civ@mail.mil) 410-306-2565

#### Supporting Facility: Multiple Experimental Facilities that Utilize the Following (APG)

- Flash radiography sources including 150, 300, 450, and 1000 KeV

- Computed radiography using Kodak imaging plates and imaging plate scanner
- Lasers; IPG 2 watt 1550 nm laser and Spectral Physics 6 watt 532 nm laser
- High speed oscilloscopes (numerous 1 GHz bandwidth and one 16 GHz bandwidth)
- Numerous delay generators and timing equipment
- Four channels of 10 GHz Photonic Doppler Velocimetry
- Cordin 222-16 intensified gated framing camera (16 images); SIM 8 frame intensified gated framing camera
- Four Photron high speed cameras;
- High voltage firing set capable of setting off numerous detonators (RP-80 like)

## Protection Technologies

Understanding conventional and unconventional methods for defeating combinations of chemical energy warhead anti-armor threats including rocket propelled grenades (RPG), anti-tank guided missiles (ATGM), explosively formed penetrators (EFP) and related improvised explosive device (IED) threats. Explore and develop hybrid and/or adaptive protection technologies to defeat a range of anti-armor chemical energy warhead threats. Investigations would involve a using a wide range of available resources including analytic models, scalable continuum mechanics codes, high performance computing assets, and multiple ballistic experimental facilities

**Principal Investigator:** John Runyeon [john.w.runyeon.civ@mail.mil](mailto:john.w.runyeon.civ@mail.mil) (410) 278-6568

### ATGM, RPG, EFP and IED Defeat (APG)

Explore and develop hybrid and/or adaptive protection technologies to defeat a range of anti-armor chemical energy warhead threats. Investigations would involve a using a wide range of available resources including analytic models, scalable continuum mechanics codes, high performance computing assets, and multiple ballistic experimental facilities.

**Principal Investigator:** John Runyeon [john.w.runyeon.civ@mail.mil](mailto:john.w.runyeon.civ@mail.mil) (410) 278-6568

### Supporting Facilities: Multi-Scale and Multi-Rate Experimental Mechanics Laboratory (APG)

- Multi-Threat Armor Branch Experimental Facility 7 and 7a (full-scale explosive events) with significant diagnostic capabilities for high-rate ballistic events
- DoD Super-Computing Resource Center with significant classified and unclassified computing capability
- Numerous related ARL, APG and Army facilities that provide support to protection research.

## Dynamic Failure of Materials at Extreme States

Discover the underlying mechanisms associated with material fracture, failure, and high pressure transformations/instabilities that occur at very high loading rates, pressures, temperatures, and magnetic fields; create engineering-level models of the underlying mechanisms, and structure the models in a manner consistent for implementation into advanced computational mechanics codes.

**Principal Investigator:** Todd Bjerke [todd.w.bjerke2.civ@mail.mil](mailto:todd.w.bjerke2.civ@mail.mil) (410) 278-5819

#### **Modeling of Dynamic Failure at Extreme States (APG)**

Discover the underlying mechanisms associated with material fracture, failure, and high pressure transformations/instabilities that occur at very high loading rates, pressures, temperatures, and magnetic fields; create engineering-level models of the underlying mechanisms, and structure the models in a manner consistent for implementation into advanced computational mechanics codes.

**Principal Investigator:** Todd Bjerke [todd.w.bjerke2.civ@mail.mil](mailto:todd.w.bjerke2.civ@mail.mil) (410) 278-5819

#### **Supporting Facilities: Dynamic Fracture Laboratory (APG)**

High-rate loading device and state-of-the-art instrumentation to isolate and probe individual fracture and failure mechanisms.

**Equipment Available:** Small diameter gas gun with customizable impact chamber, coherent gradient sensing equipment, high-powered laser, method of caustics, ultrafast 64- channel two-dimensional IR detector array for measuring thermal emissions during crack propagation, strain gages, ultra high speed imaging cameras.

#### **Supporting Facilities: Shock and Impact Physics Laboratory (APG)**

Impact laboratory for studying the effects of extreme shock pressures, temperatures, coupled electromagnetic fields, and ballistic penetration in materials.

**Equipment Available:** Suite of large diameter single and two-stage light gas guns, plate impact shock physics impact chambers, ballistic impact chambers, pulsed x-ray and high speed optical imaging systems, multi-point VISAR systems, simultaneous pressure-shear impact and shock-recovery capabilities, and extreme magnetic field coils.

### **Low-Cost Hyper-Accurate Weapons**

Research estimation and control algorithms while leveraging high-performance, low-power computing capabilities to solve complex engagement problems that are currently not feasible.

**Principal Investigator:** Mark Ilg [mark.d.ilg.civ@mail.mil](mailto:mark.d.ilg.civ@mail.mil) (410) 306-0780

#### **Supporting Facility: Guidance Navigation and Control Laboratory (GN&C) (APG)**

Facility for developing GN&C systems for gun-launched munitions. Conduct hardware in-the-loop simulations and prototyping of guidance electronics and actuation systems.

**Equipment Available:** Spriant GNSS 8000 - Global Navigation Simulator; Antenna Characterization Chamber; Gun Shock Loading Table; MEMs IMU Calibration Equipment; Helmholtz Coil; Mechanical Prototyping Equipment; MyData PCB Assembly Equipment.

### **Modeling Development and Validation Via Novel Experimental Diagnostics**

This work encompasses fundamental research in electromagnetism and solid mechanics. A close synergism between theory and experiment is continuously sought, and close collaboration between experimentalists and

modelers is considered mandatory. The theoretical work can vary from largely analytical, which relies only on physics-based PC programs, to full-scale hydrocode simulations. The experimental work employs sophisticated diagnostics that can be used to measure electrical and thermodynamic properties for purposes of comparison with theory. Specific research projects in electrodynamics or plasma physics with an emphasis on conductors moving in EM fields, gasses under extreme conditions, and/or development of unique experimental diagnostics for physics-based model or hydrocode validation

**Principal Investigator:** Casey Uhlig      [willard.c.uhlig.civ@mail.mil](mailto:willard.c.uhlig.civ@mail.mil)      (410) 278-3997

**Supporting Facility:** EM Laboratory and Experimental Ballistic Facilities (APG)

Experimental facilities with pulsed power production and measurement capabilities, and high-velocity impact events.

**Equipment Available:** Pulsed-power equipment, high-speed video (Photron, Phantom, Ultra 24, Shimatzu), video tracking, high-speed spectroscopic imaging.

## Penetration Mechanics

High-velocity penetration into soft, brittle, and ductile materials. Fracture and failure behaviors.

**Principal Investigator:** Jim Newill      [james.f.newill.civ@mail.mil](mailto:james.f.newill.civ@mail.mil)      (410) 278-6004

**Penetration Behavior of Brittle and Ductile Materials (APG)**

Experimental and modeling and simulation for high-velocity impact.

**Principal Investigator:** Brian Schuster      [brian.e.schuster.civ@mail.mil](mailto:brian.e.schuster.civ@mail.mil)      (410) 278-6733

**Supporting Facility:** High-Velocity Impact Research Facility (APG)

Facility for studying the penetration behaviors of soft and hard targets, which are both brittle and ductile.

**Equipment Available:** Launchers, flash radiograph station.

## Tactical Laser Systems

Tactical and long-range atmospheric imaging, laser communications, and directed energy systems are under development. R&D includes advanced hybrid parallel live image acquisition and processing based on adaptive optical and analog/digital computation; maximizing tactical directed-energy laser beam irradiance through adaptive coherent beam combining and control techniques; and mitigation and adaptive turbulence correction in long-range atmospheric propagation for laser communication and directed energy weapon systems.

**Principal Investigator:** Jony Jiang Liu      [jony.j.liu.civ@mail.mil](mailto:jony.j.liu.civ@mail.mil)      (301) 394-1442

**Supporting Facility: Intelligent Optics Laboratory (IOL) (ALC)**

The IOL is equipped to support sophisticated investigations in adaptive and nonlinear optics, advanced imaging and image processing, and laser communications for ground-to-ground and other applications. A variety of state-of-the-art adaptive optics, wave front diagnostics, and image processing tools are used to support advanced techniques for simulation, imaging, and laser communication system performance.

**Principal Investigator:**     Chatt Williamson     [chatt.c.williamson.civ@mail.mil](mailto:chatt.c.williamson.civ@mail.mil)     (301) 394-1771

**Science of Cyber Security**

Develop a fundamental understanding of cyber phenomena, including aspects of human attackers, cyber defenders, and end users, so that fundamental laws, theories, and theoretically grounded and empirically validated models can be applied to a broad range of Army domains, applications, and environments.

**Principal Investigators:**     Ananthram Swami     [ananthram.swami.civ@mail.mil](mailto:ananthram.swami.civ@mail.mil)     (301) 394-2486  
   Alex Kott     [alexander.kott1.civ@mail.mil](mailto:alexander.kott1.civ@mail.mil)     (301) 394-1507

**Networked Trust and Its Impact on Security (ALC)**

Develop models of networked trust and its impact on cyber security, and experimental validation with a mixture of agent models and HiTL testing.

**Principal Investigators:**

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**Supporting Facility: Cyber Lab (ALC)**

Live test bed for monitoring, collecting, and testing computer networks.



## Human Sciences

ARL's research in Human Sciences is focused on gaining a greater understanding of individual physical, perceptual, and cognitive performance in the context of interface with the environment, with other individuals and groups, with technology, and with information. Additionally, the behavior of groups, ranging in scale from small teams to societies and cultures, is of particular interest. Understanding gained through these efforts will lead to technological developments that are expected to vastly improve Soldier-system performance and training effectiveness.

Human sciences are those scientific disciplines whose central objects of study are the phenomena that cause, shape, or result from the behaviors of humans, including their actions, their interactions with each other, and their interactions with the physical world. ARL's Human Sciences research is focused on humans as part of a larger system and how humans *interface* with other elements of the system. Elemental *interfaces* of particular interest are the physical environment, including the brain/body relationship within the individual, other humans through one-to-many and one-to-one dynamics, and technology including materiel and information.

Innovations in this area are expected to enhance Soldier physical capabilities by balancing load, improving protection, and enhancing performance. Further, aided and augmented sensory systems matched to individual capabilities and tuned to the operational environment are expected to significantly impact Warfighter situational awareness. In addition, knowledge gained in this area is expected to facilitate the efficient management of Warfighter cognitive load to ensure high proficiency in Army-relevant environments. Warfighter interactions with intelligent systems will be guided by principles derived from brain and behavior fundamental research—a cornerstone of ARL's Human Sciences research. Additionally, applications of these technologies and methodologies in the full range of social and cultural environments—*based on an understanding of networked communications, relationships, and dynamics across diverse social structures*—are expected to be important in shaping the future operational environment for the Army of 2030 and beyond.

ARL's Human Sciences emphasis areas include Human-Physical Interface, Human-Human Interface, and Human-Technology Interface.

**Human-Physical Interface** fundamental research focuses on better understanding the relationship between the brain and the body, and interactions with the physical environment. Fundamental understanding gained in genetics and genomics, molecular biology, and human biochemistry and their impacts on brain structure-function coupling are expected to be essential in augmenting Warfighter performance. Physical-cognitive interactions—especially in the operational environment—are expected to influence Warfighter behavior, learning and decision making, and multisensory perception.

**Human-Human Interface** fundamental research is focused on better understanding one-to-one, one-to-many, and many-to-many interactions. The focus of this effort is on providing and evaluating effective personnel training, leader development, and team building through fundamental understanding and enhancement of motivation, physical resilience, cognitive resilience, and trust. Understanding and exploitation of the fundamental aspects of social networks dynamics; organizational structure optimization; and ethics, values, trust, social-cultural, economic, and geopolitical effects are expected to be critical in influencing group dynamics and performance.

**Human-Technology Interface** fundamental research is focused on understanding how humans interact with materiel and information. Fundamental research areas of interest include ergonomics and biomechanics to increase Soldier performance while simultaneously minimizing the probability of injury, physical augmentation to improve physical load management, wearable and implantable systems and devices for protection and for medical applications, and brain-computer interactions dedicated to understanding and enhancing cognitive performance and protection against cognitive harm.

Active research areas and specific projects seeking Open Campus collaborative engagement include:

### Soldier Auditory Situation Awareness

Models of auditory detection, identification, and localization that incorporate communications devices and personal protective gear and inform design and development of such devices.

**Principal Investigator:** Angélique Scharine [angelique.a.scharine.civ@mail.mil](mailto:angelique.a.scharine.civ@mail.mil) (410) 278-5957

### Identification of Military-Relevant Sound Events in Complex Operational Environments (APG)

Auditory information is often the first alert to events occurring in an environment. Recognition of sound sources can inform the Soldier of relevant events occurring in his surroundings. However, the science of sound identification is still relatively unexplored and highly dependent on context. In order to develop Soldier training and military aids, we seek to characterize auditory scenes by identifying auditory events important in the spectrum of military operations. This requires that we understand the features that allow the listener to recognize and identify aspects of relevant sound-source events. Models of these source and sound feature relationships have several applications. They can be used to predict Soldier performance in complex environments as well as develop training paradigms, either to train Soldiers in the identification of sounds themselves or to design realistic virtual training simulations. This work may include studies in sound source identification, development of sensory training tools and paradigms, and perception modeling of auditory and multimodal perception.

**Principal Investigator:** Angélique Scharine [angelique.scharine@us.army.mil](mailto:angelique.scharine@us.army.mil) (410) 278-5957

### Stealth Military Operations and Force Protection (APG)

The object of this research is to identify ways to reduce the auditory information available to enemy forces about individual Soldier and squad activities by minimizing and manipulating one's (individual or squad) auditory signature. This research involves various methods of manipulating the surrounding environment in order to hide the Soldier's presence, deceive the enemy by simulating the Soldier's presence at a different location, and project false information about the strength of the actual force. Data obtained could guide the creation of devices and procedures that mask, multiply, or misdirect the auditory information available to the enemy. This requires the extension of the current understanding of sound identification principles and their application within different contexts. In addition, this may include an understanding of the perceptual principles that induce change deafness. This understanding must include the multimodal cues that drive the real-world processing of one's operational environment.

**Principal Investigator:** Angélique Scharine [angelique.scharine@us.army.mil](mailto:angelique.scharine@us.army.mil) (410) 278-5957

### Auditory Situation Awareness in Complex Acoustic Environments (APG)

ARL is investigating the effects of complex acoustical environments on Soldier performance. Acoustic signals are often the first evidence of activity or a presence, and they are the only type of information about the surrounding environment that is available to the Soldier regardless of the time of day and from all directions. Detection of acoustic signals and recognition of acoustic signatures, and the directions from which they come, are critical because they may mean the difference between life and death. The primary research goal is to describe and predict the effects of auditory features present in urban military operations on Soldier auditory awareness and to quantify these effects on performance. Auditory situation awareness is defined as the ability to detect, recognize, and localize sound events. Urban acoustic environments include the effects of reverberation, direct and indirect sound pathways, background and impulse noise, movement, and mutual masking of multiple sound sources, including self-made Soldier sounds. Perception and high-level mental processing of these events are also dependent on the Soldier's mission, knowledge of the physical environment, and attentional workload. This research addresses issues not traditionally considered separately in auditory research because the complexities of the military auditory environment demand it. Data obtained from this research form the basis for determining the effects of Soldier equipment and spatial situation on auditory performance and feed various models of Soldier performance.

**Principal Investigator:** Angélique Scharine [angelique.scharine@us.army.mil](mailto:angelique.scharine@us.army.mil) (410) 278-5957

#### **Effect of Signal Processing on Auditory Spatial Perception (APG)**

Increasingly, Soldiers are being provided with radios and headsets for use with their radios. Because these headsets provide hearing protection from loud noises and some form of hearing restoration via externally mounted microphones, these tactical communications and protection systems (TCAPS) are viewed by many as a significant improvement. Soldiers, historically reluctant to wear hearing protection, may increase their compliance with hearing conservation guidelines if they are provided with communications capability. Further, the "ambient situation awareness" capability provided by the microphones is sometimes touted as "enhanced hearing" or as "combat hearing aids" because they allow the user to set the level and even provide some amplification. However, these devices also alter the cues used for auditory spatial perception. Most notably, the level of sounds passed through the headset from the ambient microphones is limited to prevent the user from being exposed to unsafe noise levels. This is achieved in various ways. The system can simply shut off and not transmit sounds above a certain intensity level. Or it can compress the range of levels transmitted, passing lower levels through unchanged but reducing the level as a function of intensity for higher levels. This compression changes the relative level cues that are the main source of distance perception cues. It is unknown the degree to which this occurs or the operational effect of such changes. The object of this research is to understand the degree to which sensitivity to distance cues is affected, the degree to which this is a function of experience, and the operational impact of such changes.

**Principal Investigator:** Angélique Scharine [angelique.scharine@us.army.mil](mailto:angelique.scharine@us.army.mil) (410) 278-5957

#### **Bone Conduction (BC) Perception and Communication Systems**

Analyze sound pathways, brain response, and/or factors that influence bone conduction effectiveness. Examine BC in novel contexts. Improve devices and mounting systems.

**Principal Investigator:** Kimberly Pollard [kimberly.a.pollard.civ@mail.mil](mailto:kimberly.a.pollard.civ@mail.mil) (410) 278-5842

#### **Bone Conduction Perception: Physiology (APG)**

Humans can hear sounds through air conduction (the pathway that starts with the external ear) and bone conduction (through vibrations of the skull). While air conduction is the dominant mode of hearing, bone conduction can be very useful in various military and security operations. Radio and audio signals can be converted into skull vibration by vibrators located on the head, and skull vibrations during speech production can be picked up by bone microphones (accelerometers) and transmitted over audio and radio channels. There is some evidence that air- and bone-conducted signals may be processed differently at the cochlear and retrocochlear levels, but it is not clear. Similarly, it is not clear if there are any differences in brain processing of sounds conducted by bone stimulation of audible and ultrasound stimuli. This research opportunity may involve analysis of bone conduction pathways in the head, collection of brain recordings during auditory task, implementation of advanced brain signal processing methods, and optimization of air- and bone-conducted signals for speech recognition and comprehension under various operational conditions.

**Principal Investigator:** Piotr Franaszczuk      [piotr.j.franaszczuk.civ@mail.mil](mailto:piotr.j.franaszczuk.civ@mail.mil)      (410) 278-8003

### Tactile Communication

Investigate the effects of alternative forms of communication in military environments, specifically, head tactile communication and phenomena for Soldier and squad communications. Develop, advance, and miniaturize head tactile equipment for field experimentation. Investigate tactile and BC synergy.

**Principal Investigator:** Kimberly Myles      [kimberly.p.myles.civ@mail.mil](mailto:kimberly.p.myles.civ@mail.mil)      (410) 278-5998

### Tactile & Bone Conduction Communication

Tactile displays can provide information to Warfighters when other sensory modalities, such as hearing and vision, are cognitively overloaded. ARL is investigating the use of tactile displays for enhancing communication in adverse military environments, including a head-mounted application. A head-mounted tactile device would intuitively present directional or collective stimulation and would quietly warn or aid in navigation without competing for visual or auditory attention. In addition, current tactile transducers can provide both a tactile and an auditory sensation depending on the excitation frequency used such as from slow (10 Hz) and fast (250 Hz) mechanical stimulation of specialized receptors in the skin. Research may include the optimization of tactile signals, determining the most efficient operation mode (displacement, velocity, acceleration) for tactile transducers, miniaturization of head-mounted tactile devices, and person-to-person communication.

**Principal Investigator:** Joel Kalb      [joel.kalb@us.army.mil](mailto:joel.kalb@us.army.mil)      (410) 278-5977

### Multi-modal Human Responses Incorporating Confidence Metrics for Human State Estimation

Develop techniques to estimate human states and confidence measures in those state estimates from multi-modal physiological and behavioral data to assess state-based changes in performance over time.

**Principal Investigator:** Kaleb McDowell      [kaleb.g.mcdowell.civ@mail.mil](mailto:kaleb.g.mcdowell.civ@mail.mil)      (410) 278-1453

## Advancing EEG Signal Processing Techniques

Refine methods for detecting and extracting neural artifacts from EEG data.

**Principal Investigator:** Scott Kerick    scott.e.kerick.civ@mail.mil    (410) 278-5833

**Supporting Facility:** BIRS Imaging Analysis Site Laboratory (APG)

Independently managed Linux (RHEL 6) high-end computing cluster with all workstations tied to dedicated central multicore server. Workstations use a wide variety of contemporary EEG and MRI analysis tools including, but not limited to Matlab, EEGLab, BCILab, FieldTrip, BrainStorm, Scan, FSL, AFNI, FreeSurfer, Connectome Mapper, and DSI Studio.

**Equipment Available:** Qty 13 Dell Precision T7500 workstations with 64-96 Gb RAM & 8-12 2.2Ghz cores. All use Matlab with several toolboxes. Qty 1 Dell PowerEdge R910 with 32 core, 512 Gb RAM running Matlab Distributed Computing Server, and Qty (2) Dell PowerVault storage arrays totaling > 36 Tb storage.

**Supporting Facility:** Mission Impact Neuro-Inspired Design (MIND)

**Laboratory (APG)**

Laboratory facility including multiple electrically isolated, acoustically attenuated chambers (one large for large-group studies) and a central control room specifically designed for neurophysiological research. Facility includes access to a uniquely large, wide range of EEG systems from a variety of both established and recent start-up manufacturers (e.g. Biosemi, ABM, Emotiv, Mindo). Systems range in design from conventional low-noise amplified to ultra-portable, wireless, low-profile “dry” systems designed for use in freely mobile applications.

**Equipment Available:** Several eye trackers, including FaceLab, SMI, TOBII, & SmartEye; Trigno full-motion EMG & Accelerometry; Several EEG systems, including: Biosemi 64 Ch (qty 3), Biosemi 256 Ch (qty 2), ABM X10, ABM X24, Emotiv Epoc (Qty 3), Quasar 9ch HMS, Mindo4, Mindo16 (Qty 2), Mindo 32 (Qty 3), and Mindo 64.

## Technologies Enabling Collection of Pervasive Real-World Neuroimaging Data

Research into hardware and software solutions enabling pervasive, mobile neuroimaging investigation. This work includes the development of novel electrode and system technologies to enable long term, mobile recording of high-density electroencephalography from the scalp, including multi-aspect, multi-modality methods. Work additionally includes algorithms and methods for artifact rejection, filtering, and source separation of data collected from real-world neuroimaging data, and novel schemes for validating the efficacy of new, unproven methods of physiological data collection.

**Principal Investigator:** Dave Hairston    william.d.hairston4.civ@mail.mil    (410) 278-5925

## Psychological Responses of Physical and Cognitive Loading During Locomotion (APG)

Investigate survey data from subjects that participated in a physically and cognitively demanding task to determine whether subjective responses correlate with physiological responses.

**Principal Investigator:** Dave Hairston      william.d.hairston4.civ@mail.mil      (410) 278-5925

## Cortical Dynamics of Everyday Tasks in Real-World Environments

Research the influence of everyday events and environments on cortical processes. This research entails the investigation of the cortical processes associated with locomotion and the interaction between cognitive and physical loading on brain dynamics. In addition, this work also focuses on neuroimaging in real-world environments in order to study the neural response to both chronic and acute occupational stress and fatigue.

**Principal Investigator:** Dave Hairston      william.d.hairston4.civ@mail.mil      (410) 278-5925

### **Supporting Facility: BIRS Imaging Analysis Site Laboratory (APG)**

Independently managed Linux (RHEL 6) high-end computing cluster with all workstations tied to dedicated central multicore server. Workstations use a wide variety of contemporary EEG and MRI analysis tools including, but not limited to Matlab, EEGLab, BCILab, FieldTrip, BrainStorm, Scan, FSL, AFNI, FreeSurfer, Connectome Mapper, and DSI Studio.

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## Brain Structure Function Coupling

Develop multiscale understanding of the relationship between the brain's physical structure, its dynamic electrochemical functioning, and human behavior.

Principal Investigator: Jean Vettel [jean.m.vettel.civ@mail.mil](mailto:jean.m.vettel.civ@mail.mil) (410) 278-7431

### Understanding Brain Structure-Function Relationships in Healthy Individuals (APG)

ARL's Neuroscience program seeks to enable revolutionary advances in Soldier-system performance by integrating modern neuroscience with computer science and engineering to both enhance our understanding of Soldier function in complex operational settings and develop novel and effective means to enhance systems design. ARL's neuroscience efforts focus on the scientific study of the brain and its interaction with technology. We are looking for post-doctoral colleagues to advance efforts in brain structure-function couplings. The brain structure-function couplings effort incorporates several neuroimaging methods to image structure (MPRAGE, diffusion imaging) and function (mostly EEG with some fMRI) to derive structural and functional networks for an individual. Ongoing research examines the sensitivity and reliability of reconstruction methods to derive structural tractography from diffusion-weighted imaging as well as the ability of functional connectivity measures to derive task-relevant, functional networks. The successful applicant will implement and evaluate metrics (e.g., network-level descriptions) that quantify individual differences in structural and/or functional connectivity.

Principal Investigator: Jean Vettel [jean.m.vettel.civ@mail.mil](mailto:jean.m.vettel.civ@mail.mil) (410) 278-7431

## Soldier Performance - Interaction of Physical and Cognitive Performance

Perform research and analysis to understand the effects of physical and cognitive stress (and their interaction) on Soldier performance in laboratory and dismounted operational environments.

Principal Investigator: Michael LaFiandra [michael.e.lafiandra.civ@mail.mil](mailto:michael.e.lafiandra.civ@mail.mil) (410) 278-5973

### Interaction of Physical and Cognitive Performance for the Dismounted Soldier (APG)

The project investigates the effects of physical and cognitive stress on Soldier performance and determines new ways of measuring these stressors in operational environments.

Principal Investigator: Michael LaFiandra [michael.lafiandra@us.army.mil](mailto:michael.lafiandra@us.army.mil) (410) 278-5973

### Biomechanics for a Dismounted Warrior (APG)

Our biomechanics program focuses on understanding the effects of equipment on the Soldier and Soldier-system performance. Specifically, we examine Soldier-equipment issues for dismounted Soldiers (i.e., Soldiers not riding in vehicles). Biomechanical analyses are used to minimize the negative effects of this equipment and to provide design guidance for maximizing the positive effects. Our current biomechanics laboratory is being replaced by a state-of-the-art 2700 square foot biomechanics lab with an integrated force plate treadmill, portable cardio-pulmonary and EMG systems, and motion capture system.

Principal Investigator: Michael LaFiandra [michael.e.lafiandra.civ@mail.mil](mailto:michael.e.lafiandra.civ@mail.mil) (410) 278-5973

**Supporting Facility: Soldier Performance and Equipment Advanced Research Facility (APG)**

Facility designed to impose and measure the effects of physical and cognitive stress on Soldier performance in a dismounted operational environment.

**Equipment Available:** 3000 sq-ft biomechanics lab with 12 camera motion capture system, 2 x 16 channel EMG systems, 2 portable oxygen consumption measurement devices, inertial measurement units, fully instrumented 500 meter obstacle course with 22 obstacles, WiFi network.

**Supporting Facility: C4ISR Laboratory (APG)**

Immersive environment for evaluating effects of cognitive stress on Soldier performance.

**Equipment Available:** Nine individual rooms (whisper rooms) each housing a large-screen monitor connected to a networked gaming system capable of allowing Soldier subjects in each room to interact in the virtual environment.

**Supporting Facility: Tactical Environment Simulation Facility (TESF) (APG)**

Immersive environment for evaluating effects of physical and cognitive stress on Soldier performance.

**Equipment Available:** Immersive cave (4 sides, completely enclosed CAVE) with OmniDirectional Treadmill (ODT) capable of immersing Soldier subjects in simulated environment and allowing them to walk freely in that environment.

## Social Cognitive Network Science

We are conducting a cross-disciplinary basic and applied research program to significantly advance the state-of-the-art in how communication networks influence and are influenced by human behavior in the context of military decision making. The research will contribute to the development of theory, methods, measures, models, and understanding of networked communications and the social-cognitive implications of those networks. Research environments range from computational modeling, to networked simulations in a laboratory environment, to field exercises. Studies will look at the effects of technology on cognitive workload, team collaboration, organizational effectiveness, and decision making. Cyber security is also a major topic.

**Principal Investigator:** Norbou Buchler      [norbou.buchler.civ@mail.mil](mailto:norbou.buchler.civ@mail.mil)      (410) 278-9403

**Network Science: Social Networks and Cognitive Factors (APG)**

Communication and information technology has transformed military capabilities to engage in network-centric operations. To an unprecedented degree, Soldiers collaborate in distributed networks across areas of operations often using specialized information systems and communication platforms to manage the imperative to collect and analyze intelligence, secure a populace, deliver supplies, and wage war. Our interdisciplinary approach leverages convergent methodologies to include experimental psychology (experimental design), cognitive science (modeling), human factors (usability, work domain analysis), and network science (social network analysis). The emerging interdisciplinary field of network science is of particular interest to our research

efforts to address a preeminent challenge posed by the sheer complexity of human-in-the-loop networks and may serve to guide the systematic convergence of technology, information, and people. The objective of our research is to understand the effects that networked systems have on human cognition and team dynamics, and to develop models, theories, and analytical approaches to examine cognitive processes, information properties, and to identify key network dynamics across the social-cognitive-technological levels. Networked systems do not necessarily take into account the processing capabilities and limitations of the human brain. Cognitive performance—evidenced by effective distributed collaboration and decision making— may or may not be well-supported by our networks and Soldier technologies. It is imperative that we understand what aspects of network operations cause an undue cognitive burden to the command staff and dismounted Soldiers who collaborate with and pull information from media such as radios, text messages, emails, battle command systems, sensors, and ground and air unmanned assets. The objective is to develop decision aids to help integrate information management for users who especially are required to rapidly and efficiently process information from sources at multiple levels. A better understanding is required of system usage on communication flow, information transfer, cognitive workload, situational awareness, expertise, individual differences, and their effects on performance. This knowledge is instrumental to the development of battle command decision support tools that improve information relevance (data aggregation), and team collaboration and synchronization (alert/aiding capabilities). This work should ultimately result in networked information systems well-aligned to the needs of the Warfighter by matching system requirements to Soldier cognition and collaborations through an enhanced understanding of human-system team interactions.

**Principal Investigator:** Norbou Buchler      norbou.buchler.civ@mail.mil      (410) 278-9403

### Supporting Facility: Cognitive Assessment, Simulation & Engineering Laboratory (APG)

Stand-alone behavioral sciences lab that has capabilities for a variety of research topics, especially multidisciplinary topics.

**Equipment Available:** Isolation, sound attenuated research chambers; robotics lab; simulated mission command centers (various levels); VirTra 300 degree immersive simulation facility, with tetherless rifle firing capability and threat-fire shock belt for realism; psychophysiological measures.

### Human-Robot Interaction

This research area is of critical importance to the Army for its understanding of the complexities and dynamics of human interaction with unmanned systems across domains (e.g., land, air) and capability levels (e.g., autonomy, manual control). We are developing programs to carry out fundamental research involving complex equipment, emerging technologies, and scientific phenomena pertaining to humans and autonomous systems. The work applies methods and techniques of cognitive and experimental psychology, human factors engineering, and/or computer science to the understanding and solution of human factors issues involving unmanned systems across a range of military operations. The research will contribute to the development of theory, models, methods, and measures for understanding the interdependencies between the cognitive, social, information, and communication aspects of interaction with unmanned autonomous systems and ultimately to

help align Soldier and system capabilities in real time to support effective performance across a broad spectrum of military operations.

Principal Investigator: Susan Hill [susan.g.hill.civ@mail.mil](mailto:susan.g.hill.civ@mail.mil) (410) 278-6237

#### **Enhancing Performance of Human-Robot Interaction (HRI) Teams (APG)**

Military operations depend more and more on an array of unmanned technology, such as ground vehicles, air vehicles, sensors, and microsystems. The inclusion of unmanned systems, information networks, and advanced sensor suites is intended to enhance operational performance and Soldier safety. However, the implications of these technologies for human use are not always fully understood nor are they always considered during design. The Soldier's role for interaction with unmanned systems is broad, ranging from robot operator to information manager to information consumer. The goal of our HRI program is to maximize the effectiveness of integrating unmanned technology into the Soldier team through the development of state-of-the-art Soldier-system interactions. We seek to identify tools, techniques, and measures that can improve and assess performance with unmanned systems across multiple environments. Specific issues to be addressed include unmanned and manned vehicle autonomy, intuitive communications and interfaces, supervisory control, teaming, situation awareness, and strategies for workload management. ARL's Human Research and Engineering Directorate is currently conducting HRI research at APG, MD. Research environments include laboratory, simulation, and field environments.

Principal Investigator: Susan Hill [susan.g.hill.civ@mail.mil](mailto:susan.g.hill.civ@mail.mil) (410) 278-6237

#### **Human-Robot Interaction and Advanced Displays for Human-Vehicle Interaction (Orlando, FL)**

ARL is conducting research on human-robot interaction (HRI) and advanced displays for human-vehicle interaction (HVI). HRI and HVI are both complex work environments where the human operator engages in multiple simultaneous goal-oriented tasks (e.g., communication, navigation, reconnaissance, security, and control of other systems while on the move). Other HRI research involves experiments on live and simulated robot teleoperation; specific research areas include display technologies (e.g., multimodal displays and stereoscopic displays) and automation techniques (e.g., adaptive automation) to enhance the robotics operator's performance in multitasking environments. Our research on advanced displays for HVI focuses on augmented/overlaid information on vehicle vision block for indirect-vision driving and embedded training. State-of-the-art simulators and equipment are used in both research areas.

Principal Investigator: Jessie Chen [jessie.chen@us.army.mil](mailto:jessie.chen@us.army.mil) (407) 384-5435

#### **Supporting Facility: Cognitive Assessment, Simulation & Engineering Laboratory (APG)**

Stand-alone behavioral sciences lab which has capabilities for a variety of research topics, especially multi-disciplinary topics.

**Equipment Available:** Isolation, sound attenuated research chambers; robotics lab; simulated mission command centers (various levels); VirTra 300 degree immersive simulation facility, with tetherless rifle firing capability and threat-fire shock belt for realism; psychophysiological measures.

## Manned-Unmanned Collaborative Teaming

Investigate factors that determine effective teams, decision making, and performance, specifically for manned/unmanned teams in ground and aviation systems.

Principal Investigator: Tom Davis [thomas.w.davis.civ@mail.mil](mailto:thomas.w.davis.civ@mail.mil) (256) 876-2048

### **Manned and Unmanned Collaborative Systems Integration**

Advancement in technology has greatly improved the capability of military systems. Mission requirements are now dictating system interoperability levels that go beyond the traditional human-machine interface. Asymmetric threats are dictating collaborations among a mission system now defined by multiple systems. These higher-order system-of-system interactions are introducing challenges to the way technology is designed, constructed, measured, and evaluated. The Collaborative Unmanned System Integration Laboratory (CUSIL) is conducting research to expand our Nation's understanding of the dynamic human-machine relationships already deployed and underway with the military's fleet of optionally piloted vehicles. Core research initiatives address the demands placed on the Soldiers' mental resources required to manage attention, make decisions, and coordinate crew activities and communication.

Principal Investigator: Tom Davis [thomas.w.davis.civ@mail.mil](mailto:thomas.w.davis.civ@mail.mil) (256) 876-2048

## Supporting Facility: Manned-Unmanned Systems Integration Laboratory (Huntsville, AL)

Manned-Unmanned Collaborative Teaming Laboratory dedicated to investigating factors that impact teams and their decision making.

**Equipment Available:** Eight (8) networked distributed team workstations with virtual battle space, EEG and EKG monitoring, head motion and eye tracking, six-DOF Pholomus Motion Tracking.

## Decision Fusion for Human-autonomy Interactions

Develop general techniques for fusing decisions from both human and autonomous agents in order to improve performance at joint human-autonomous tasks. Investigate active transfer learning through brain computer interaction by using novel machine learning methods to better identify artifacts in unlabeled neural data.

Advance development of machine learning and classification techniques for increasing the robustness of Army-relevant brain-computer interaction technologies (BCIT), using statistical classification and machine learning methods, semisupervised graphical learning, analysis of large-scale data sets, advanced signal processing, multivariate statistics, computer programming, experimental design, EEG, and physiological recording and analysis. Emphasis on translational research and technology development that will leverage years of research and candidate will support the short-term goal (5 years) of developing a working proof-of-concept system to demonstrate the viability BCITs in operational environments.

Principal Investigator: Brent Lance [brent.j.lance.civ@mail.mil](mailto:brent.j.lance.civ@mail.mil) (410) 278-5943

## Human System Integration - Modeling and Simulation

Research, develop, and apply human systems integration (HSI) techniques, tools, and technologies to ensure MANPRINT goals, constraints, and human performance measures are achieved.

Principal Investigators: Diane Mitchell [diane.k.mitchell.civ@mail.mil](mailto:diane.k.mitchell.civ@mail.mil) (410) 278-5861  
Jock Grynovicki [jock.o.grynovicki.civ@mail.mil](mailto:jock.o.grynovicki.civ@mail.mil) (410) 278-5956

## Supporting Facility: System Assessment and Usability Laboratory (SAUL) (APG)

Research, develop, and apply human systems integration (HSI) techniques, tools, and technologies to ensure MANPRINT goals, constraints, and human performance measures are achieved. Conduct MANPRINT assessments on graphical user interface (GUI). Execute usability studies on software user interfaces.

**Equipment Available:** HSI-Tools: IMPRINT enhanced with automation and library of activities and micromodels, Job Assessment Software System (JASS) to define and measure human aptitudes; MIL-STD-1472 Physical Accommodation Companion Software; C3TRACE - Command, Control, and Communication Environment.

## Medical Human Factors

The ARL Field Element at Fort Sam Houston, TX, conducts medically-related human factors engineering research and consults with the Army Medical Department Center and School. Lines-of-study include attrition during medical Advanced Individual Training; performance modeling; evaluation and design of advanced technologies to ensure ease of use, display congruency, efficiency and effectiveness; an examination of mindfulness based stress reduction delivered through a virtual world (teaching mindfulness [meditation] to Soldiers and veterans in-person and via Second Life); study of the interactive metronome as an effective intervention to enhance performance; study of devices to help identify mild TBI cases.

Principal Investigator: Valerie Rice [valerie.j.rice.civ@mail.mil](mailto:valerie.j.rice.civ@mail.mil) (210) 221-2007

## Medical Technologies

Conducts research to prototype the most realistic and effective medical simulation-based training systems. Research is conducted into key enabling technologies that include silicon and synthetic biological tissues; embedded odors; blood and other body fluids; variable physiology; sensors; after action review capabilities; 3D anatomy; virtual tissue; and virtual patient visualization. HRED-STTC has a Medical Lab supporting this research area. Internships and Postdocs are available. There is currently one Intern working in this research area.

Principal Investigators: Christine Allen [christine.allen2@us.army.mil](mailto:christine.allen2@us.army.mil) (407) 384-5119  
Tere Sotomayor [teresita.sottomayor@us.army.mil](mailto:teresita.sottomayor@us.army.mil) (407) 384-3969



## Adaptive Tutoring

Investigate methods to enable computer-based tutoring systems to adapt instruction based on learner states (cognitive, affective, and competence). Experimentally assess learner state variables (self-reported, observed, physiological, and behavioral) to accurately model the learner's cognitive / affective state and adapt content and interactions to meet learner needs. The Learning in Intelligent Tutoring Environments (LITE) Laboratory supports a wide range of research into adaptive tutoring. There is one current postdoc student working in this technology area

**Principal Investigator:** Robert Sottolare      [robert.sottolare@us.army.mil](mailto:robert.sottolare@us.army.mil)      (407) 384-3007

### **Adaptive Computer-Based Tutoring Research (Orlando, FL)**

The goal of this research is to develop methods to assess the cognitive and affective states of trainees in near-real time and then use this state data to adapt computer-based instruction to enhance/accelerate learning outcomes (e.g., knowledge and skill acquisition, retention). The research program has three thrusts: trainee modeling, authoring and expert modeling, and instructional strategy selection. Trainee modeling includes assessment techniques for determining cognitive and affective states through behavioral and physiological sensing techniques and machine learning algorithms. Authoring and expert modeling research explores the automated development of instructional content and expert models used as standards to define the trainee's performance level. Finally, instructional strategy selection research develops and assesses machine learning techniques to automatically guide the tutor's performance (e.g., interaction with the trainee, selection of instructional content and feedback, pace, and challenge level of instruction).

**Mentor:** Robert Sottolare      [robert.sottolare@us.army.mil](mailto:robert.sottolare@us.army.mil)      (407) 616-1860

## Advanced Simulation

The purpose of the Soldier-Centered Army Learning Environment (SCALE) is to research and prototype a technology-enabled, data-driven learning environment for integrated training across multiple platforms (personal computers, mobile devices, games, virtual worlds, social media, and classroom teaching methods). Research is conducted to determine how and when Soldiers learn best in collaborative environments and to assess performances; capture and share individual expertise and lessons learned; and develop user-friendly authoring tools that support rapid development of content across several platforms.

**Principal Investigator:** Chris Gaughan      [chris.gaughan@us.army.mil](mailto:chris.gaughan@us.army.mil)      (407) 384-3323

## Live Training Technologies

Conduct research into training and operational simulations in the Army Live Training Domain. Technologies being researched include hybrid position and navigation sensors, next-generation lasers, embedded simulations in operational systems, enemy predictive technologies, micro-cloud architectures, and tracking technologies inside structures. A laser lab supports this research area.

**Principal Investigators:** Frank Tucker [frank.tucker@us.army.mil](mailto:frank.tucker@us.army.mil) (407) 384-5448  
 Bonnie Eifert [latika.eifert@us.army.mil](mailto:latika.eifert@us.army.mil) (407) 384-5338

### Virtual Worlds

Research into modeling all aspects of Massively Multiple Online Gaming (MMOG). ARL has an in-house laboratory supporting virtual world research.

**Principal Investigator:** Tami Griffith [tami.griffith@us.army.mil](mailto:tami.griffith@us.army.mil) (407) 384-3636

### Virtual Humans

Conduct research to assess the social effects of virtual humans / artificial intelligence. Areas of research include natural language processing, gestures, responses, emotion, and photo-realistic graphics. Objective is to rapidly create virtual human characters.

**Principal Investigator:** John Hart [john.hart@us.army.mil](mailto:john.hart@us.army.mil) (407) 384-3012

### Dismounted Soldiers

Conduct research into technologies to blend live and virtual training simulations. Research technologies include virtual locomotion, avatar group behaviors, visual stimulates, positioning sensors, artificial intelligence, and see-through helmet-mounted displays. ARL has a Dismounted Soldiers lab that supports this research area.

**Principal Investigators:** Pat Garrity [pat.garrity@us.army.mil](mailto:pat.garrity@us.army.mil) (407) 384-3663  
 Frank Dean [frank.dean@us.army.mil](mailto:frank.dean@us.army.mil) (407) 384-3877

## Assessment and Analysis

The Assessment and Analysis research area is focused on development and application of analytical tools and methodologies to quantitatively assess the military utility of Army, DoD, and select foreign combat systems. In addition to the development of novel assessment and analysis capabilities, knowledge and understanding drawn from ARL's other technical campaigns are leveraged to help influence requirements for future Army systems. Exemplary of Army and DoD-relevant high-interest areas supported through these efforts include ballistic effectiveness, personnel armor susceptibility; platform armor susceptibility; information systems vulnerability; system-of-systems analyses; and human performance enhancement assessment.

ARL's Assessment and Analysis research emphasis areas include Assessment of Science and Technology, Science and Technology of Assessment, Assessing Mission Capability of Materiel, and Materiel Capable of Assessing Mission Capability. These areas collectively comprise the Assessment and Analysis area, which heavily relies on ARL's research expertise and facilities in intelligent systems, cyber security, information sciences, human sciences, materials, and lethality & protection. The Assessment and Analysis area is focused on guiding the development and integration of technologies, substantially broadening the range of issues that can be addressed with analytical rigor, improving the throughput and responsiveness of the analytical processes, and developing ruggedized and ready-to-employ applications that make the full power of the laboratory's internal analysis capabilities available directly to the Army's operational force.

**Assessment of Science and Technology** concentrates on understanding the costs and benefits of R&D efforts, their readiness levels, risks, potential payoffs, and integration challenges.

**Science and Technology of Assessment** concentrates on understanding the key types of analytical problems likely to confront the Army of 2030, exploiting the latest developments by our academic and industrial partners, and performing basic and applied research to develop the powerful new tools required.

**Assessing Mission Capability of Materiel** concentrates on understanding and exploiting systems' technologies, design, and employment together with current—and likely future—state of the art to optimize future designs and to inform evaluation and acquisition decisions with analyses that are both technically sound and practically efficient. Key to this effort, are methodologies to integrate technical assessments into the science and engineering domain with considerations of mission effectiveness for the materiel's operational user.

**Materiel Capable of Assessing Mission Capability** concentrates on understanding and exploiting developments in the other S&T campaigns to evolve assessment and analysis itself from a laboratory service to a technology that we transition to the Warfighter.

Research areas and specific projects seeking Open Campus collaborative engagement are in development and will be added in future updates.

## FREQUENTLY ASKED QUESTIONS

### ***Q: Where would I be working?***

ARL is headquartered in Adelphi, MD, and occupies major sites at Aberdeen Proving Ground, MD; Research Triangle Park, NC; White Sands Missile Range, NM; and Orlando, FL. Unique facilities at our primary sites provide scientists and engineers access to world-class research centers. Opportunities currently exist at several of our major sites:

- ADELPHI LABORATORY CENTER (ALC) is located approximately 10 miles north of the center of Washington, DC, and approximately 26 miles southwest of Baltimore, MD. The center is within one mile of both I-495, also known as the Capital Beltway, and I-95. ALC is located in Montgomery and Prince George's Counties, MD.
- ABERDEEN PROVING GROUND (APG) is the Army's oldest active proving ground established on October 20, 1917, six months after the United States entered World War I. It remains one of the Army's most active and diversified installations. Situated at the head of the Chesapeake Bay, APG is surrounded by some of the best natural resources that Maryland has to offer. Located along the I-95 corridor, APG is approximately 74 miles to Philadelphia, 71 miles to Washington DC, and 32 miles to Baltimore.
- ORLANDO, FL, is the home of ARL's Simulation and Training Technology Center. It is located approximately 15 miles east of downtown Orlando, FL.
- WHITE SANDS MISSILE RANGE (WSMR) is located in the Tularosa Basin of south-central New Mexico. The headquarters area is 20 miles east of Las Cruces, NM, and 45 miles north of El Paso, TX. The range boundaries extend almost 100 miles north to south by 40 miles east to west. At almost 3,200 square miles, the range is the largest military installation in the country.

### ***Q: Are there security requirements for working with ARL?***

All personnel working at ARL must undergo a basic background check of his or her criminal and credit histories to ensure that they are "reliable, trustworthy, of good conduct and character, and loyal to the United States." The length and depth of the background investigation will depend on the position's requirements, as well as the type of security clearance if needed for a particular job, visiting scientist exchange, postdoctoral fellowship, or internship. If selected for a position that requires a security clearance, the individual will be required to complete an SF 312 Nondisclosure Agreement in accordance with Executive Order 13526 as part of their responsibility to protect sensitive information. In order to help speed the process along, candidates should begin to gather relevant information now. The forms for background checks (SF-85: Questionnaire for Non-Sensitive Positions) and (SF-86: Questionnaire for Non-Sensitive Positions) are on the Office of Personnel Management's website and can be found at <http://www.opm.gov/forms/standard-forms/>.

For U.S. Citizens: In addition to forms SF-85 and SF-86, a fingerprint card will need to be completed at the local Intel & Security Office.

For Non-U.S. Citizens: In addition to forms SF-85 and SF-86, the following is needed:

- Fingerprint card must be completed.

- Two forms of picture identification must be presented (one of which must be a valid Passport/VISA, or Resident Alien Card).

***Q: I am a foreign visiting scientist, postdoc, graduate student, or intern. Can I work at ARL?***

YES.

Non-U.S. citizen employees will be issued a Foreign National "V" Escort Required Badge as well as a Foreign National DoD Common Access Card (CAC). This badge authorizes access to designated ARL Buildings/Rooms from 8:00 am to 5:00 pm, Monday through Friday only, except Federal holidays. Access during other times and to other ARL facilities requires prior approval of the ARL Foreign Disclosure Officer (FDO).

- The ARL badge will be prominently displayed on an exterior garment above the waist, with photo and/or markings visible from the front, at all times while inside restricted areas.
- The ARL badge will need to be renewed every 30 days by visiting the Visitor Control Center and completing the necessary paperwork. The designated escort(s) are required to sign for the badge.
- The ARL badge will not be worn outside of the ARL campus. Badges will not be used for identification purposes outside of the ARL installation and facilities, and will not be used for private purposes, such as cashing checks.
- The individual bearers shall be responsible for the care and safeguarding of badges issued to them. The loss of a security badge must be reported at once, in writing, to the Intelligence and Security Division, Access Control/Badging Office.
- Visitors to ARL are subject to the restrictions used by federal law, statutes, Army, IMCOM, ALC regulations, policies and procedures, and this memorandum.
- All other activities, meetings, or events at other locations within ARL, as well as access outside the core working hours, require an escort at all times. Prior approval must be granted by the Foreign Disclosure Officer.

**FOREIGN NATIONAL ACCESS TO ARL FACILITIES:**

Foreign Nationals are welcome to ARL facilities but require prior approval or precoordination. In order to enter the facilities, Foreign National visitors must complete the following:

- |                                 |                         |
|---------------------------------|-------------------------|
| ▪ Unofficial Visit request Form | 7-10 days prior to stay |
| ▪ Official Visit request Form   | 30 days prior to stay   |

After completion of the ARL form, the request will be sent to the Foreign Disclosure Officer for approval. Once approved the individual must provide 2 forms of identification to receive the Foreign National ARL Badge.

Entrance into ARL installation typically requires:

- Entry onto ARL by any motor vehicle or other wheeled device, subjects the operator and occupants to a search of their person and vehicle by law enforcement authorities assigned to ARL as authorized by law.
- No person will drive a privately owned vehicle on the installation without having on his/her person, a valid state driver's license, vehicle registration, and proof of insurance. The owner of the vehicle is also responsible for

ensuring that any other person operating his/her vehicle is properly licensed and carries a valid license on his/her person while operating the vehicle.

- Entry will be admitted upon display of appropriate Common Access Card (CAC) or Civilian Identification Card and Civilian driver's license. Employees/Guest Researchers without a DoD ID will be stopped, their vehicle inspected, and instructed to obtain a temporary vehicle pass for that day. ARL is working to establish identification cards/processes for collaborating partners.
- Access for drivers will be at the main gate, where their vehicles may be inspected prior to entry. Parking is authorized in any of the available lots.

***Q: Will I still be able to publish my research if I work with ARL, or will my work be classified?***

Much of the work conducted at ARL is basic or applied research that can be published in open literature unless it has been determined to be "classified." Generally speaking:

- All publishable and releasable material prepared or jointly prepared by ARL employees must be reviewed and approved by the responsible supervisor; undergo a security classification, quality assurance and OPSEC review (ARL Form 1) and be approved for public release (Distribution A: Approved for public release) by the ARL Public Affairs Office.
- All publishable and releasable material prepared by a contractor or a researcher under contract to the U.S. Government must be reviewed and approved, if required by the terms of the contract, by his or her Contracting Office Technical Representative; undergo a security classification, quality assurance and OPSEC review (ARL Form 1); and be approved for public release (Distribution A: Approved for public release) by the ARL Public Affairs Office.
- ARL's Quality Assurance and OPSEC Review policy does not apply to basic research conducted by a visiting researcher that is not under contract with ARL as long as an ARL employee or qualified contractor is not a coauthor of such material. Authors or organizations not subject to mandatory reviews may submit their material to ARL to obtain advice on national security concerns.

***Q: How will the creation and assignment of any intellectual property be handled?***

Under the Bayh-Dole Act, the outside collaborator has first opportunity to file a patent for jointly created inventions. If that party decides that they don't want the "invention," they must notify ARL, and then ARL can decide if it would like to go forward and pursue patenting or other means of protecting the intellectual property.

***Q: What are government "march-in" rights?***

Government march-in rights are one of the most contentious provisions in the Bayh-Dole Act. This applies only when ARL funds the research. That is not the usual situation under Open Campus efforts. It allows the funding agency (ARL) to ignore the exclusivity of a patent awarded under the act and grant additional licenses to other "reasonable applicants." This right is strictly limited and can only be used under very specific circumstances. As of 2012, NO FEDERAL AGENCY has ever exercised these rights.



***Q: Will any intellectual property (IP) that I bring to the collaboration be protected?***

Any IP a non-Federal party brings to the collaboration MAY be protected. The non-Federal party should clearly indicate the proprietary data or property that they are claiming ownership to. ARL may or may not want to protect jointly made IP by filing a patent or other means. The non-Federal party has first election under Bayh-Dole and can file for patent protection. Under all circumstances, non-Federal IP disclosed to Federal employees during the collaboration results in a duty by the Federal employees not to disclose the information (plans, diagrams, etc.) to any non-party to the project.

***Q: Does working with a DoD lab affect one's ability to file for a patent?***

NO. Working at ARL does not affect your ability to file a patent; however, there will be additional paperwork requirements. The non-Federal party MUST fill out a DD882 report of invention form. ARL would then make a rights determination. Normally the non-Federal party (either solely inventing or jointly with ARL personnel) will have the first opportunity to file for patent protection. The rights the Government will obtain will vary with the instrument (CRDA, Cooperative Agreement, contract, etc.).

***Q: What other regulations do I need to know about to work with ARL?***

The specific regulations and policies that may apply to any person or group working with ARL will depend on what authority is being used to support the project and/or collaboration. Details concerning the relationship, cost sharing (if applicable), protection of resulting IP, identification and protection of proprietary data, facility/equipment use, and security measures will need to be identified and defined in the implementing agreement.